TELESCOPE MAKING 37

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The magazine *for*, *by*, and *about* telescope makers!

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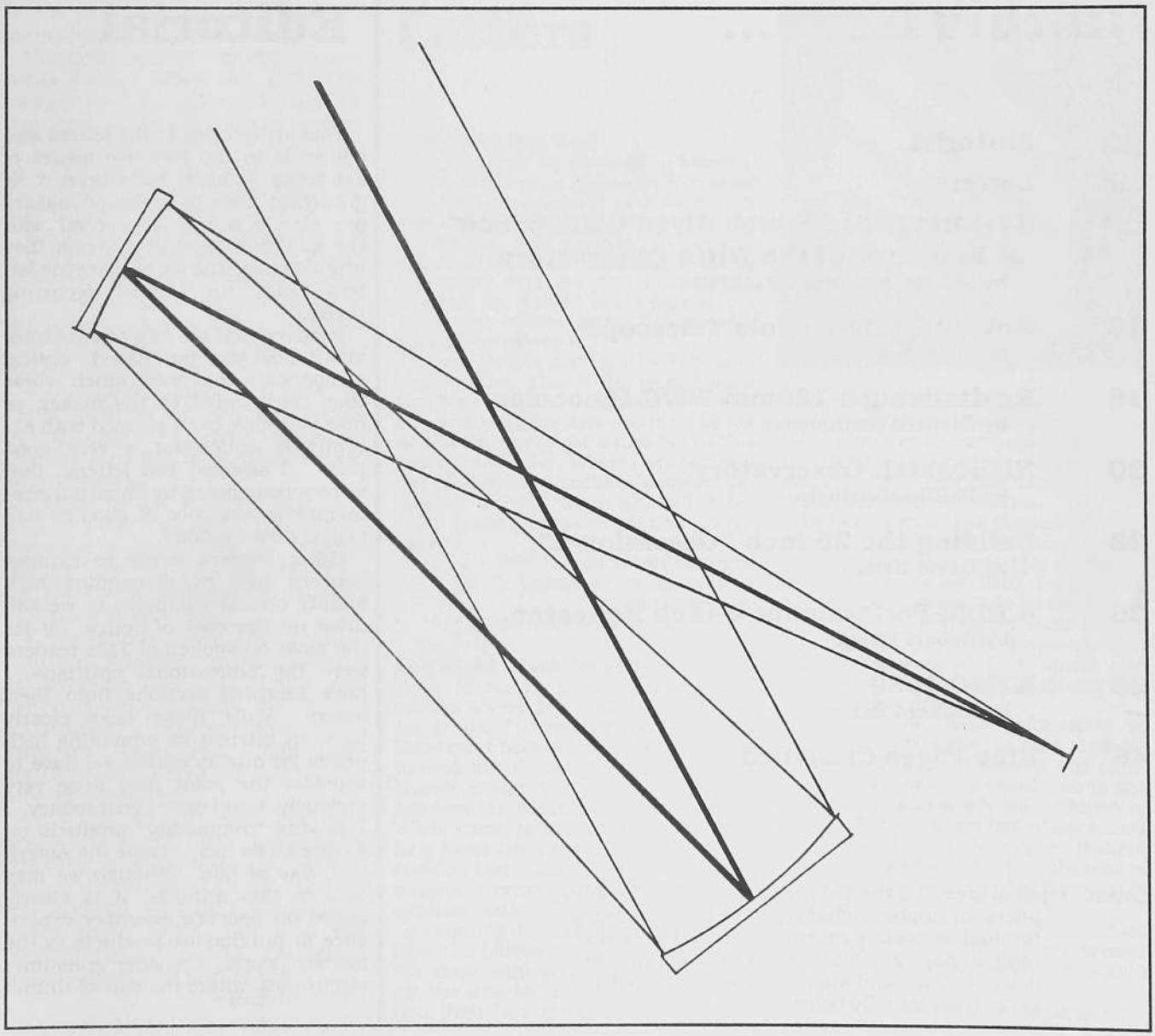

Telescope Making #37

The magazine *for*, *by*, and *about* telescope makers!

Editor: Richard Berry
Associate Editor: Robert E. Cox
Managing Editor: Stephen Cole

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Editorial

Your responses to the letters and editorials in the last two issues of Telescope Making have been most gratifying. Today's telescope makers are clearly deeply concerned with the quality of optical systems they buy and use. The accompanying letters point up several recurring themes.

Readers sent me lots of anecdotes about how you purchased optical components that were much worse than represented by the maker, or how you have been pleased with exceptional optics for a very good price. I selected two letters that were accompanied by impartial photographic evidence of good or bad claims about quality.

Other readers wrote to express concern that by demanding high quality optical components we will drive up the cost of optics. By far the most outspoken of *TM*'s readers were the professional opticians. I have exerpted sections from their letters. While these folks clearly have an interest in promoting high prices for quality optics, we have to consider the point they raise very seriously. Good optics cost money.

Buying "commodity" products on a price basis has become the American Way of Life. Although we may deplore this attitude, it is clearly based on people's everyday experience in purchasing products in the modern world. Consider consumer electronics, where the rule of thumb

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Telescope Making
21027 Crossroads Circle
P.O. Box 1612
Waukesha, WI 53187

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phone: (414) 796-8776
fax: (414) 796-0126

is "the price will fall and the performance will rise by next year."

However, quality optical components do not follow this rule. Mirrors are not stamped out by the million, but each is a unique product of the optician's craft. And if it's a bad one, it's a bad one—with results you can see every time you look through the eyepiece.

Meanwhile, back at the ranch...

• We're preparing for Kalmbach's move to new corporate headquarters—please note the new address, the new phone number, and the new fax number. We'll soon have a modem number, too.

• Our new building will have far better facilities for testing and evaluating optical systems than our current building does. That should be interesting.

• Drop by for a visit? Sure—but give us a day's warning. The new offices are located near the interestion of I-94 and Highway 18. It's a big glass-and-brick-fronted building on Crossroads Circle.

• The photo above shows Emily Johnson, telescope maker, and me at Riverside this year. Emily and her dad, Virgil, built the 4-inch squatting-dog telescope from **Build Your Own Telescope**, Emily grinding the optics and Dad making the tube and mounting.

• My apologies to several authors (you know which ones you are) for bumping stories back to *TM#38*. This issue surprised me—it filled up very quickly. Usually I would have added some pages, but with the *Voyager* flyby coming, discretion seemed the better part of valor.

—*Richard Berry*

Letters

Flats Test Out Well

Dear Richard/ Enclosed is an interferogram made on a Zygo Interferometer of a Coulter Optical 2.14-inch minor-axis diagonal flat, advertised good to 1/10-wave, and good in the test to about 1/30-wave. The fringes along the minor axis are just as straight. Not bad for $18.95 ppd.! (Ignore the diffraction effects along the extreme edge of the mirror.)

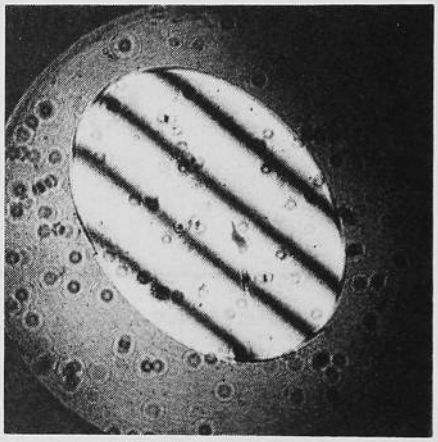
I hope people don't get too paranoid about optics. This is the second such Coulter diagonal mirror we have checked with the Zygo, so it must not be uncommon to get a nice flat in this size from Coulter. When I worked as a remodeling contractor, people frequently did not trust me. Will I become suspect because I'm now an optician?

Dan McConaughy
Lorraine Precision Optics
1319 Libby Lane
New Richmond, OH 45157

Use Right Glass for Littrow

Dear Richard/ Drew Sorenson describes a very fine 6-inch f/21 refractor of the Littrow design in *TM#36*. However, I believe a word of caution is needed about the general use of the Littrow design because it leaves little freedom to control the aberrations. While coma is of small concern in a long focus telescope and spherical aberration can always be hand corrected away if necessary, color correction is another matter.

According to thin-lens theory, the flint of a Littrow lens must have twice the dispersion of the crown in order for the lens to be achromatic. Deviation from this ratio by as little as a



few percent can result in serious chromatic error. If the ratio is greater than 2.0, color can be compensated by introducing an airspace between the elements, but this will usually cause severe spherical aberration.

In Drew's case, the glasses were selected by Chance-Pilkington specifically for the Littrow design, and overall correction is excellent. An analysis of his design shows it to be much better than the diffraction limit over a 36mm field at f/21. However, this cannot be expected from crown and flint glass combinations offered for sale by other firms.

It would be most unfortunate to make an objective to the Littrow deisgn and find out after it was completed that the color correction is not acceptable. Absolutely no criticism of Drew's fine telescope nor of his article is intended, but telescope makers should be aware that the selection of glass is essential to the success of this design.

Alan E. Gee
236 Lanitos Avenue
Sunnyvale, CA 94086

Continued on page 44...

Refurbishing the 12-inch f/15 Alvan Clark Refractor of the John H. Witte Observatory

Shortly after they organized, members of the Southeastern Iowa Astronomy Club sought access to the Clark refractor owned by the Burlington Community School District. In 1939 John H. Witte, a local businessman and amateur astronomer, had donated the telescope to the school system. Housed in a roll-off shed on top of the old Burlington High School building, the telescope was used until the late 1960s. But when a new high school was constructed in 1969/69, the Witte Foundation donated funds to purchase and install a 16-inch Cassegrain telescope on the new building. After this the Clark was rarely used.

Although we had permission from the school board to use the refractor, we didn't have free access to the telescope. The Area Education Agency (AEA-16) used the building we went through to reach the telescope, and we had to pay a $10-per-hour charge for a security guard. During one of our many discussions about this annoyance, a club member half-jokingly suggested that we should build an observatory and move the refractor to it!

It seemed ridiculous, but we couldn't forget the idea. A member had influential contacts in town, so he made some inquiries—and discovered that the school board would be willing to donate the telescope to us if we could find a site for the proposed observatory and funding for the building. Further inquiries revealed that the Witte Foundation would fund the building if the telescope could be acquired and a suitable building site found.

Our crazy idea began to seem real. We approached the conservation board to see if it would donate the land if we could obtain the money and telescope. It turned out that the Des Moines County Conservation Board was interested in developing an astronomy program. All interested parties easily reached agreement to procede with the club's plan, and construction of the new observatory began.

The Witte Observatory is located within the grounds of the Big Hollow Creek Conservation Area, and is the property of the Des Moines County Conservation Board. Through a cooperative agreement, the facility is managed by the Burlington Chapter of the Southeastern Iowa Astronomy Club, acting through an Observatory Board of Directors.

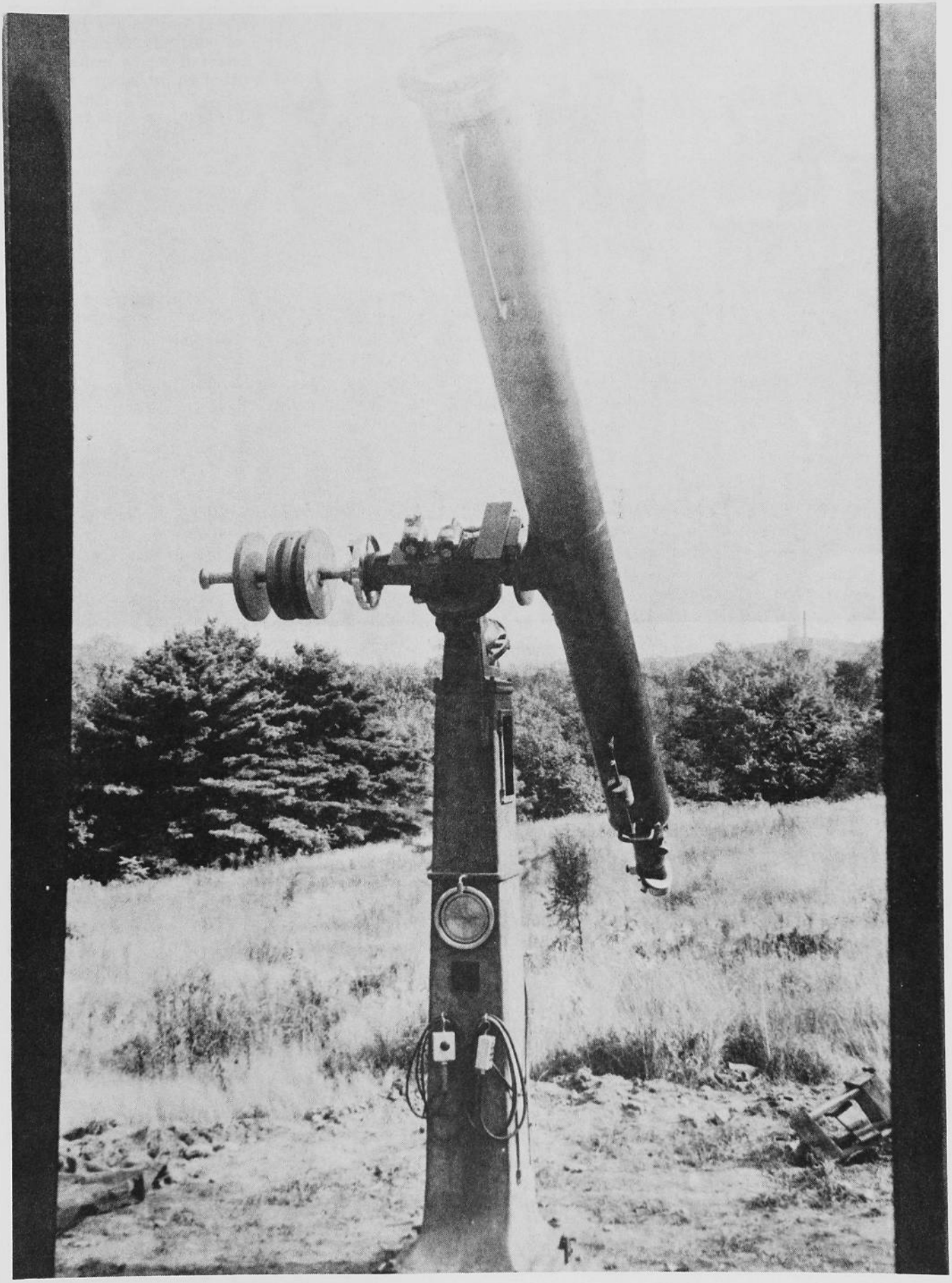
Dismantling the Telescope

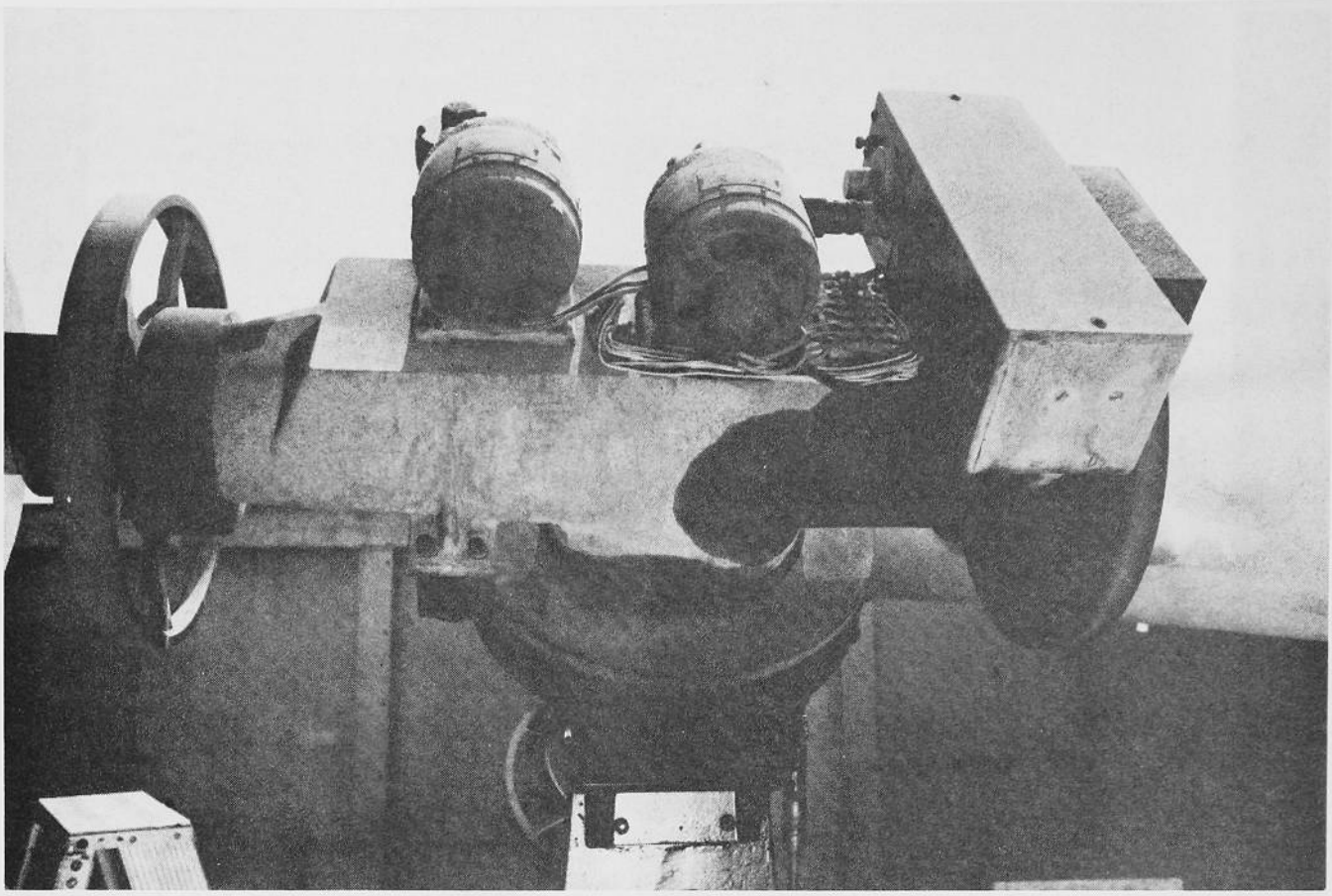
Our reponsibility was to restore the telescope. After a careful examination of the telescope, we decided that no major repairs would be needed but, because it had not been maintained and had not been in regular use for years, the telescope would require refurbishing.

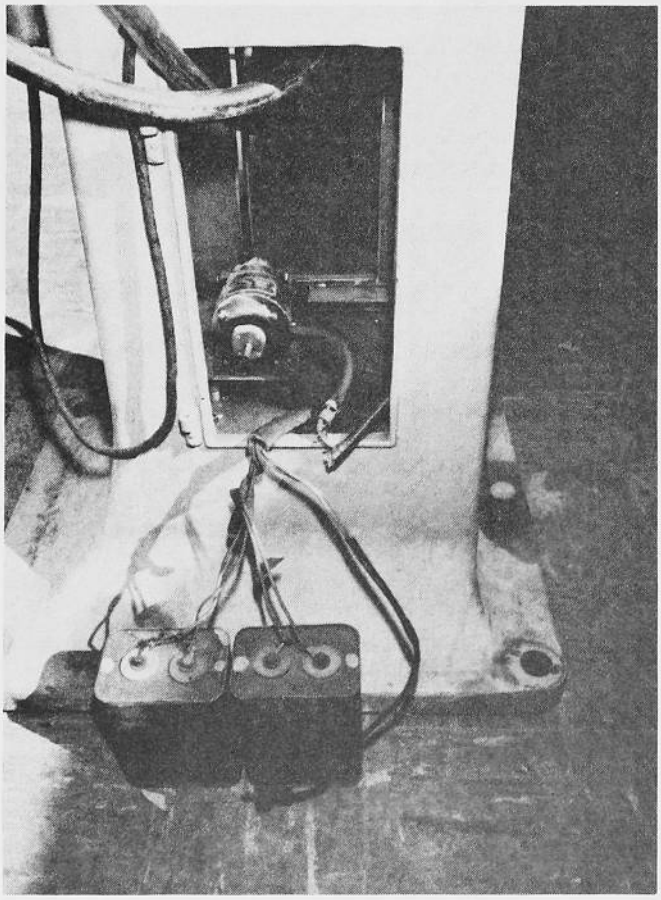
To begin the work, we placed the refractor horizontal. To stabilize it, we supported both ends of the tube with metal scaffolding and removed the counterweights. Club members then removed accessories and delicate parts from the tube. As soon as we removed the painted handholds, we realized the white-painted tube was made of brass!

We removed the 12-inch objective from the tube very carefully and carried it to the nearby industrial arts building for storage. After we had taken off the focuser and Fecker eyepiece turret, we unbolted the tube from the equatorial head and lowered it by hand from our perch atop the scaffolding. From the

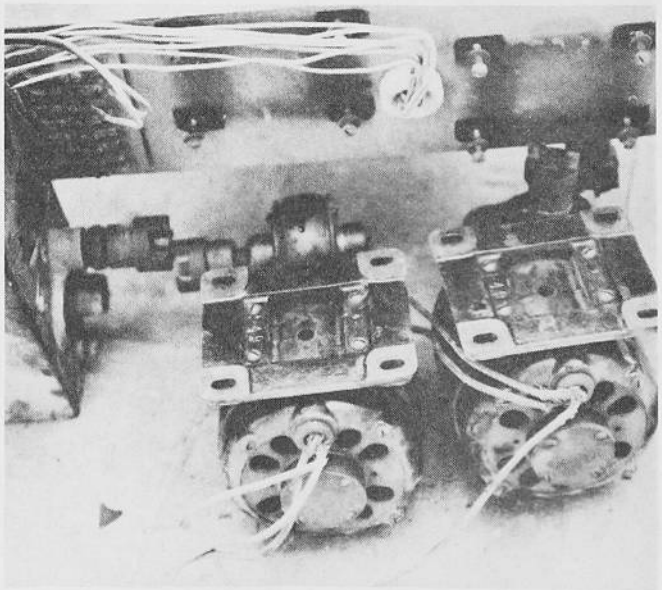
An original photograph of the telescope taken near the time of its construction, before it was put on the roof of Burlington High School.







The declination axis carried two motors, for slewing in RA and for declination slow motion. Detail of the declination axis motors. The RA drive motor had two ancient capacitors. Page opposite: The clock-drive motor and its gear train. The RA motor and its gearing. The declination drive and RA slip ring, remote readout, and differential gears.



third story roll-off roof observatory, we hand-carried the tube to Styrofoam cradles where it rested until we were ready to undertake the refurbishing.

With the tube out of the way, we loosened the bolts to the equatorial head, pedestal, and pier but did not withdraw them. The equatorial head and pedestal awaited the arrival of a crane for the 35-foot trip from the rooftop to the ground. Broeker Erection, a Burlington firm, provided a crane. For the removal of the equatorial head and cast iron pedestal, workers from the company arrived at the Apollo Middle School with a 20-ton Grove crane-equipped truck with a 100-foot boom and 30-foot jib. They picked the heavy parts off the building with the crane, using nylon straps. The equatorial head was taken to the industrial arts building and the pedestal transported directly to the Witte Observatory.

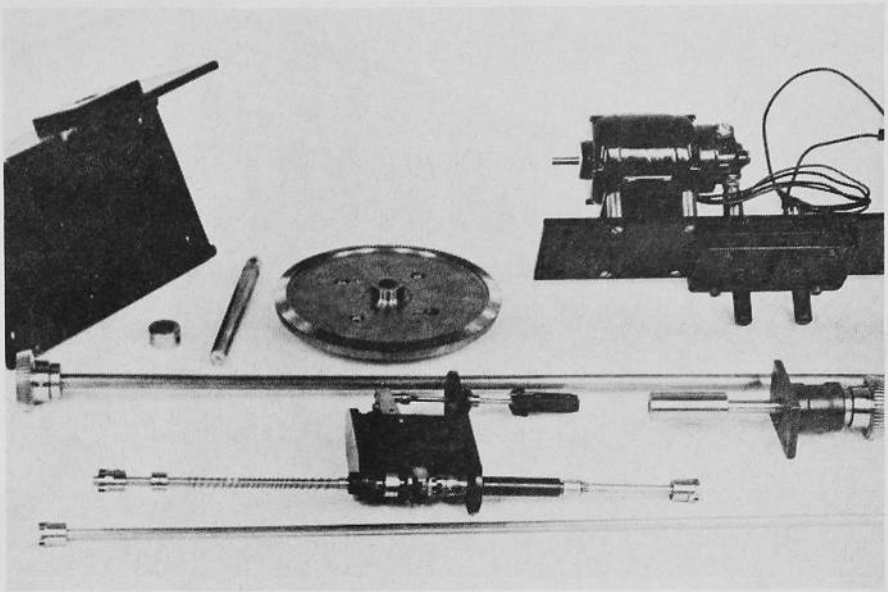
Throughout the disassembly of the telescope, we took careful notes and drew diagrams of each step. As we removed or disassembled a part, we measured and wrote down everything. We recorded not only the position of the weights and counterweights but also the size and type of bolts and nuts used to hold parts together.

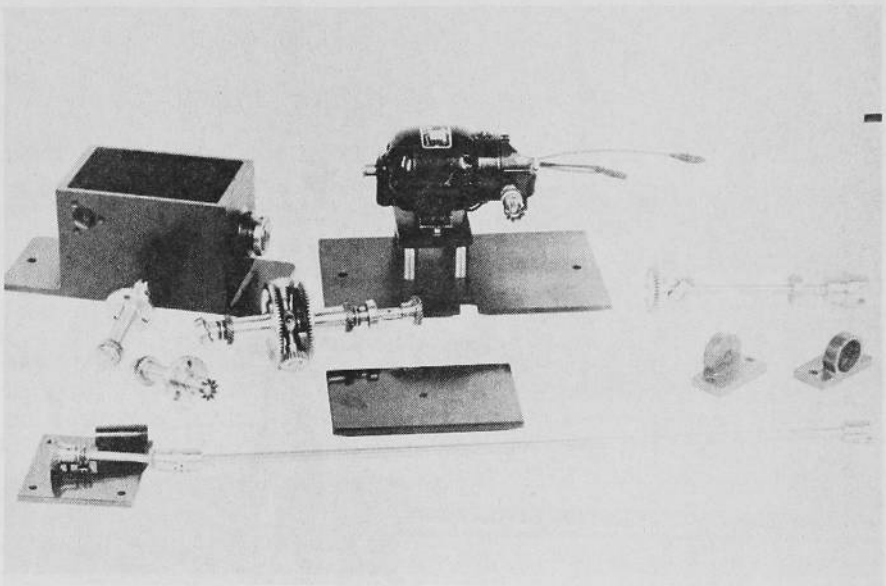
To complete the record, we took photographs of the more intricate assemblies. These photographs later served as memory joggers to show us exactly where and how pieces fit and reminded us how they should be reinstalled. To prevent confusing small parts like screws from the different subassemblies, we packaged each set of small parts together, along with a description of where they had come from.

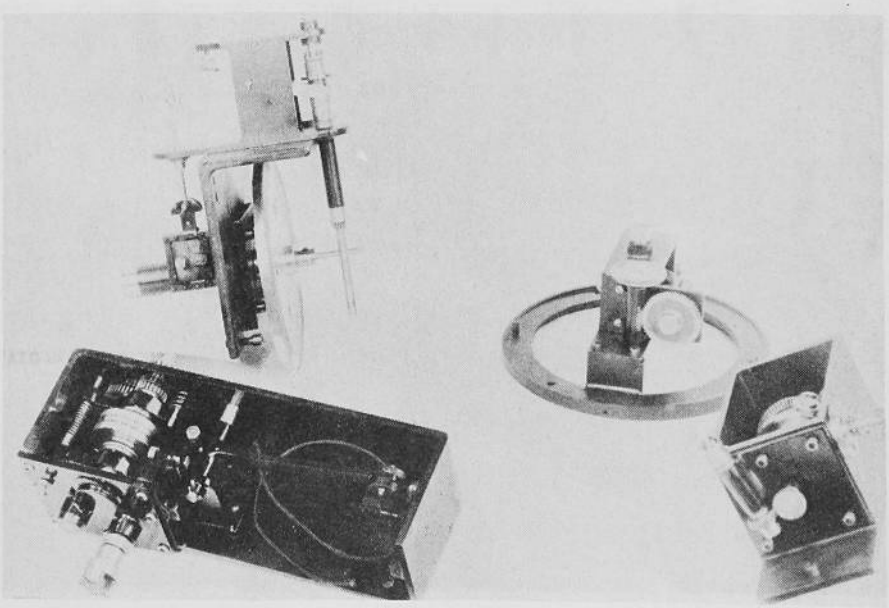
Restoring the Tube

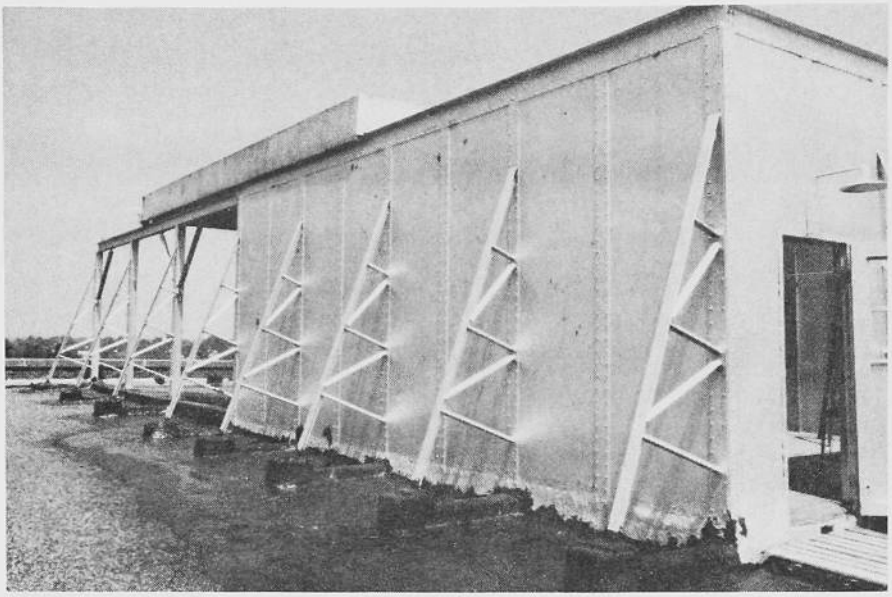
To remove the old paint from the outside of the tube, the buffing committee (Dan Carlson, Jeri Moberg, Robin Gerling, and Marion Bachtell) used a gel-type stripper and fine steel wool. They rubbed the tube with a fine grade of rubbing compound and a drill with buffing pads to take off the oxidation and start the polishing. They finished with a jeweler's rouge to obtain a bright shine. The auto paint shop at Southeastern Community College sprayed it for us with four coats of clear polyurethene sealer of the type used to "clear coat" cars.

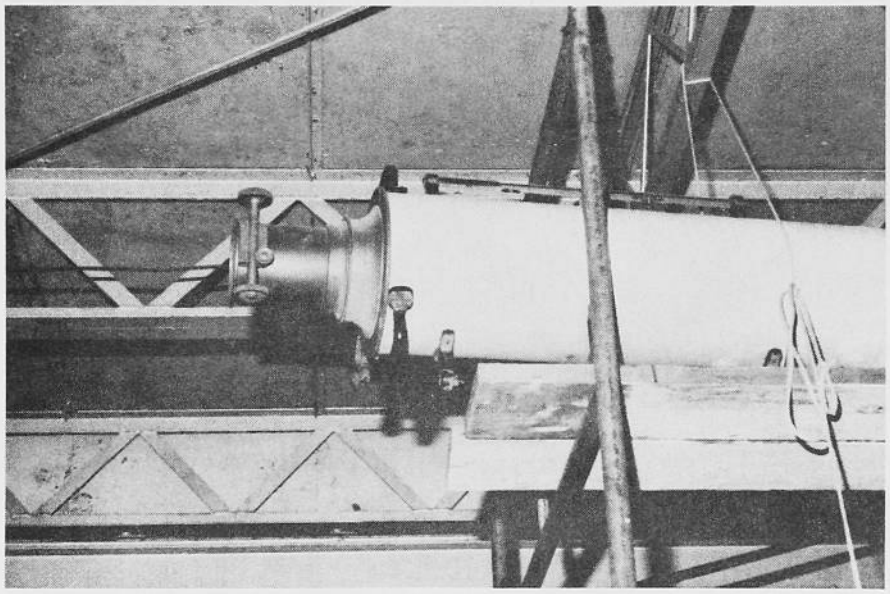
Inside the tube we found that the antireflective paint was in good condition. We decided it would not require anything other than a

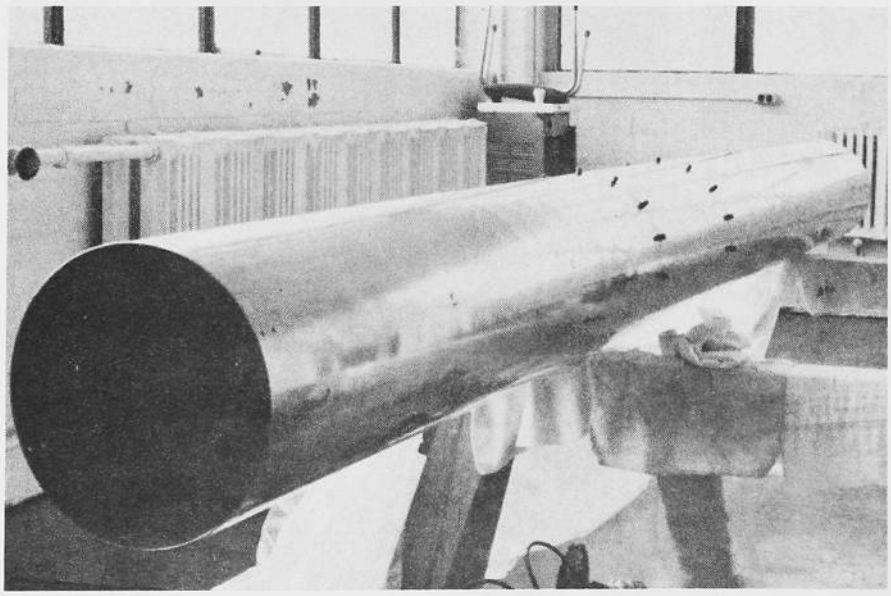












"touchup" in some areas. The four light baffles were in excellent shape, so we did not remove them.

Marion Bachtell disassembled the focuser as far as possible and then spent many hours removing the years of oxidation on the brass parts. She placed the small pieces in a bowl and soaked them in Noxol, a liquid brass cleaner. She placed rags soaked in Noxol over the larger pieces and soaked them again and again to remove the oxide.

Once the brass parts were clean, she used cuticle sticks and Q-tips to remove the Noxol from their cracks and crevices and then shined the pieces with Semi-Chrome polish. After reassembling the focuser, she coated them with Johnson Paste Wax to retard oxidation.

Because of its lens, we treated the large brass "deep-sky" eyepiece with great care during the cleaning process.

The Fecker eyepiece turret was disassembled, and because it was made of cast iron, we sanded and painted it royal blue. The handles on the tube, pier, the tube of the spotting scope, and the collar for the lens cell were all painted with a high-gloss, rust-proof, royal blue enamel, matching the Fecker eyepiece turret.

Cleaning the Objective

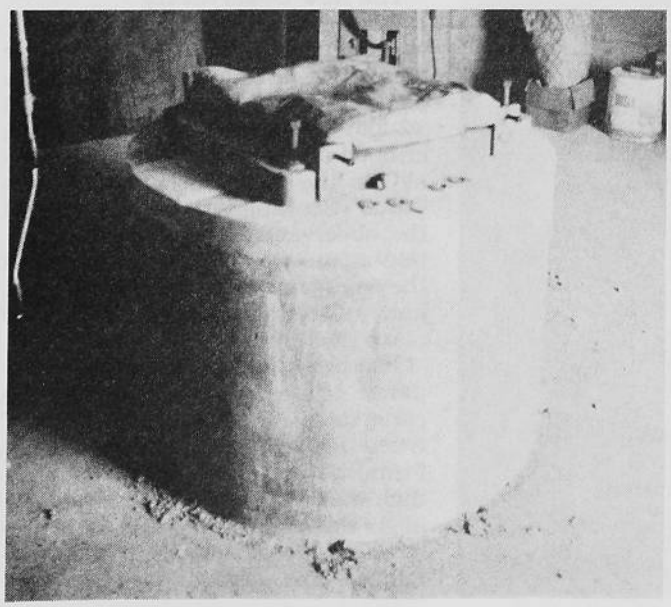
When our club took over the care and maintenance of the 12-inch f/15 Alvan Clark and Sons refractor in the spring of 1986, the front element of the objective was coated with a film of dust and dirt. It had accumulated over the previous ten to fifteen years because the scope had been used rarely.

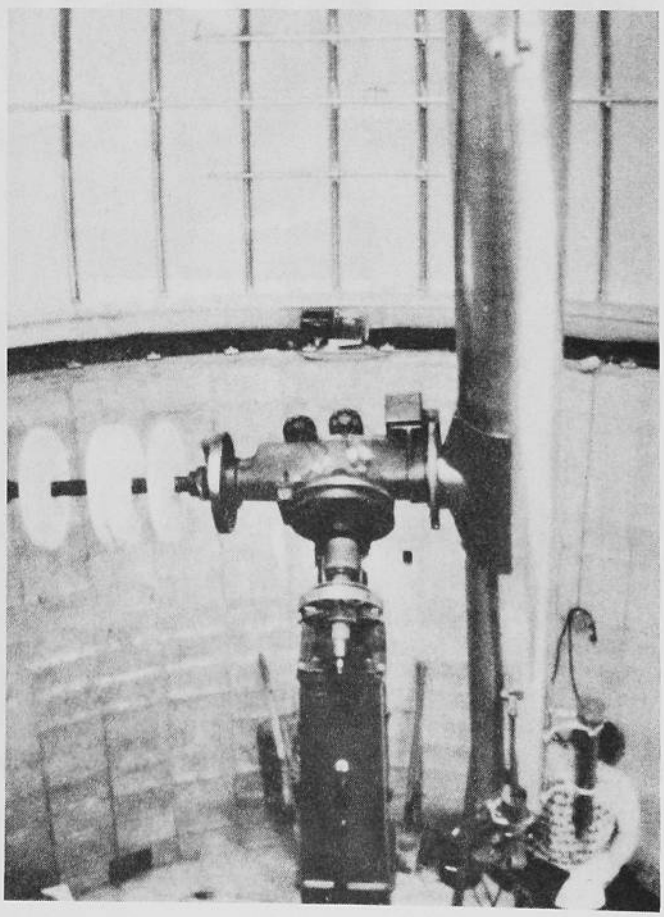
When we removed the lens cell assembly from the tube, we discovered the back surface of the lens was almost as dirty as the front element. According to people we talked to, the objective lens had last been cleaned in 1968. (The surfaces of the Clark objective are not antireflective coated.)

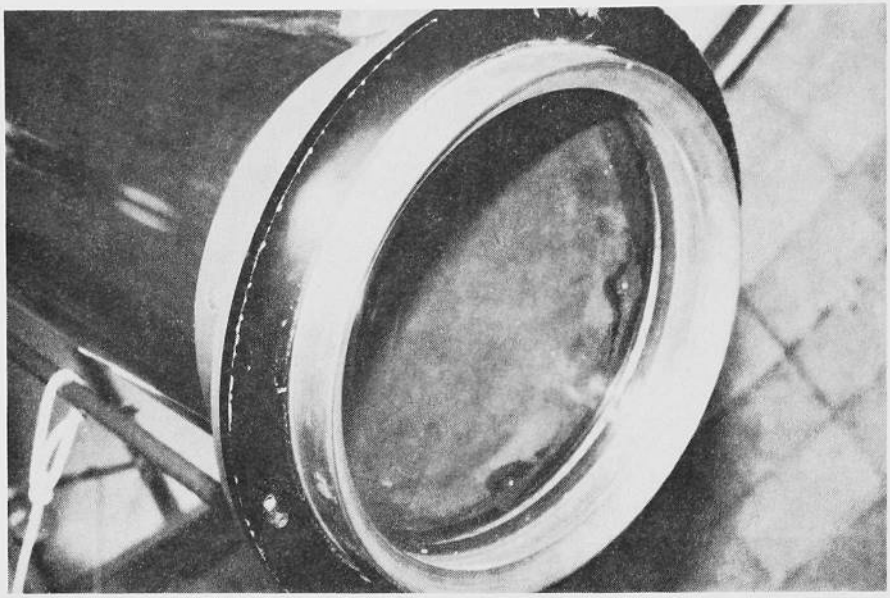
The job of cleaning the lens was assigned to Duane Gerling, Jim Blair, and Claus Benninghoven. They decided to clean only the front and rear surfaces because the inner surfaces showed no signs of dirt accumulation.

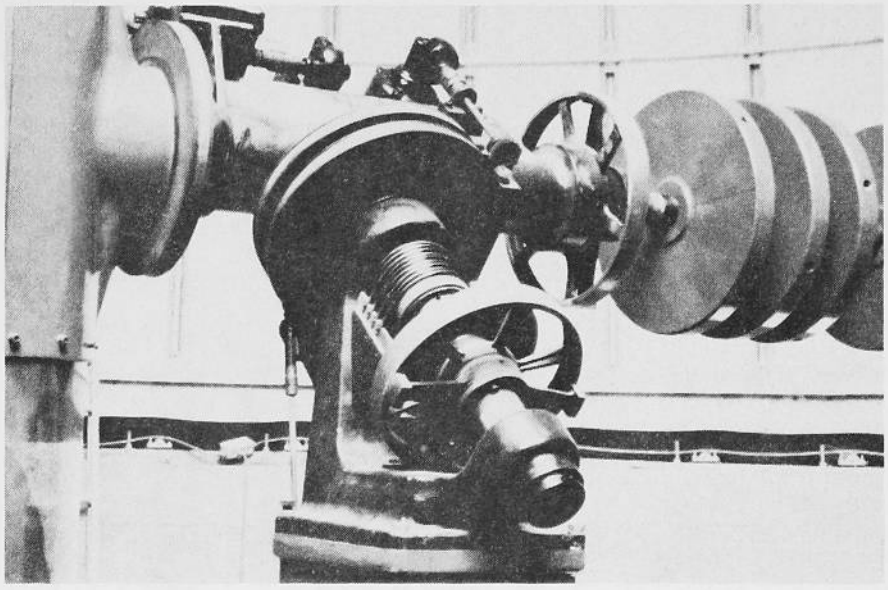
We put the lens-cell assembly face-up on a sturdy table on top of a black sheet of cardboard and inspected the lens with a bright light. A magnifying glass gave us a close-up way to check for dirt and

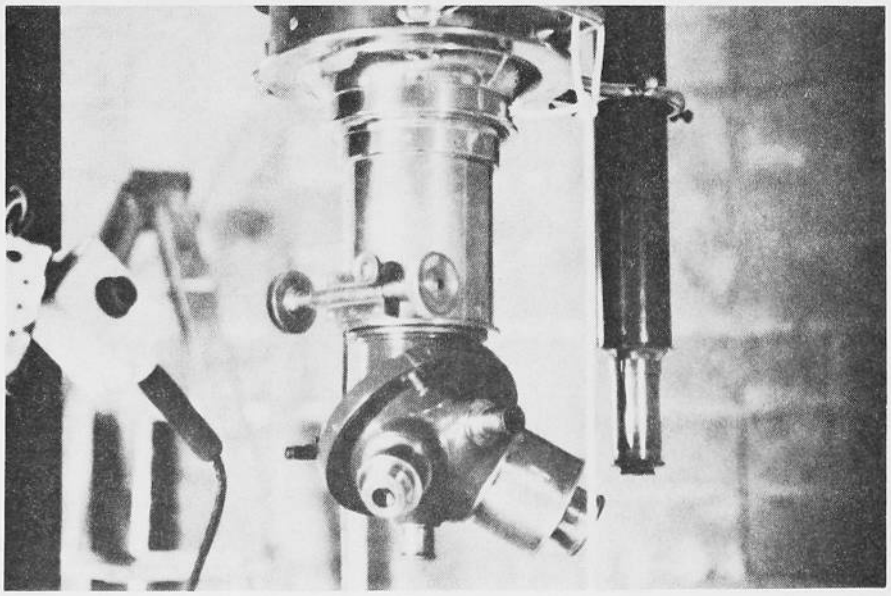
Opposite: The original roll-off roof located on the roof of the old High School. The tube cribbed with scaffolding in the old building. The 12-foot of brass tube on sawhorses for polishing. This page: The new building seen from the northwest before its completion. Putting a few final touches on the focuser. The pier and base plate in the new dome.











dust particles. We brushed and blew loose dust and dirt away with a soft sable brush and a rubber bulb syringe.

Once we were satisfied that we had dislodged all the loose particles, we set to work with the cleaning solution described in Clay Sharrod's book *A Complete Manual of Amateur Astronomy*. A thoroughly cleaned plastic bowl was filled about half way with the lens cleaner. To apply the solution to the glass, surgical grade cotton and high-quality lens tissue were used.

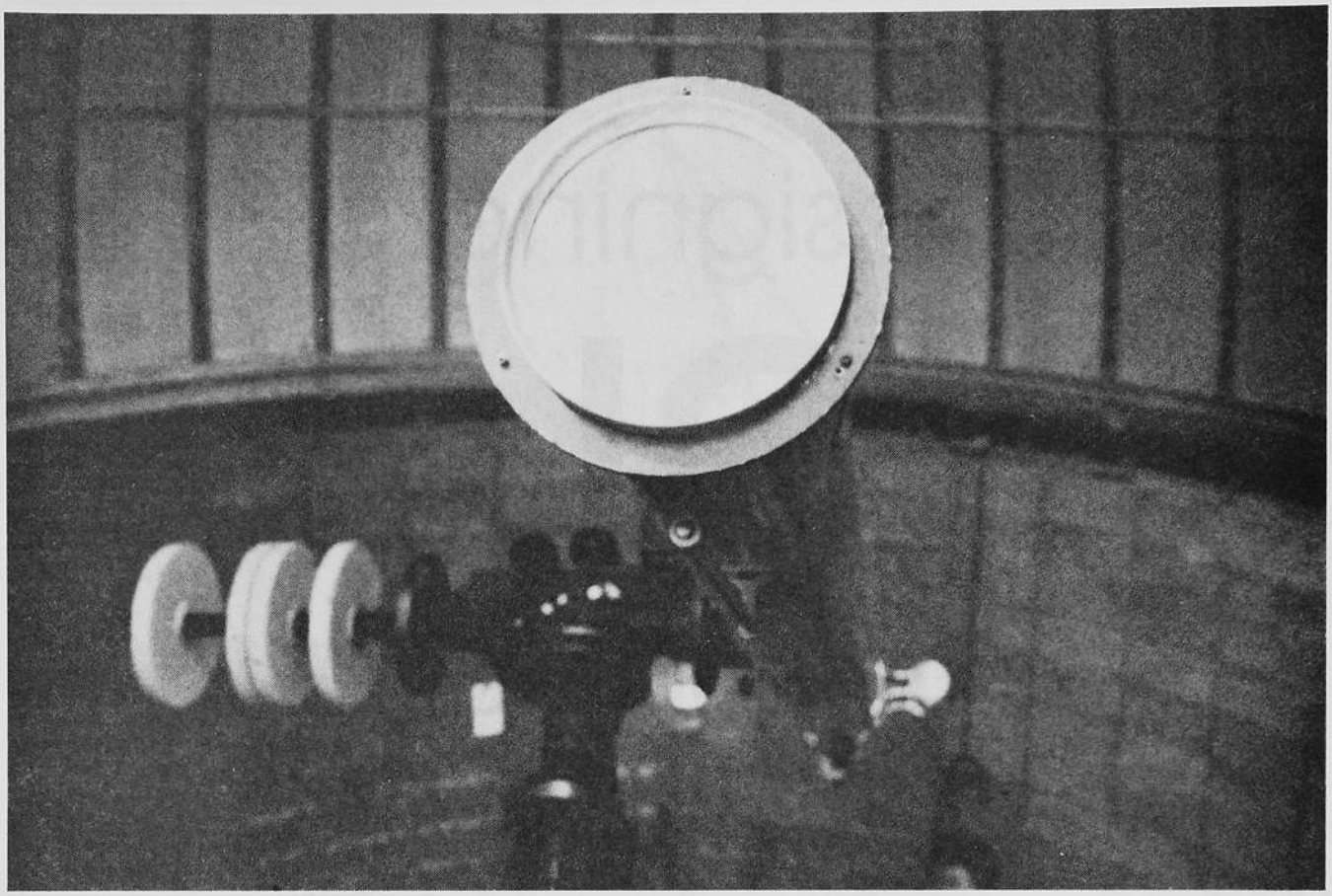
We cleaned the lens by repeating a cleaning cycle over and over. Each cycle consisted of spreading cleaning solution on the lens surface and then drying the surface by dabbing the glass with gentle pressure. To do this, a clean cotton swab fresh out of the wrapper was dipped into the solution, which was quickly distributed over the entire glass surface. Three or four wads of lens tissue were used in succession to soak up the fluid and pick up and loosened dirt. Only a dabbing motion—never wiping—was used with the tissue. Cotton swabs and lens tissues were discarded immediately after use.

After each cleaning cycle, when the surface was dry, it was thoroughly inspected under strong light with a magnifying glass. To clean the lens to our satisfaction required eight cleaning cycles for the front and five for the rear surface. At the end of the process, each surface was gently polished with the soft, dry lens tissue using parallel strokes. The only circular motion was applied along the edge of the objective.

The New Observatory

On a misty Saturday morning we wrestled the equatorial head up the tommy-lift tailgate of Ted Cockrell's pickup. We also loaded the Clark's 12-foot 4-inch polished brass tube, cribbed and blanketed for the journey to the Witte Observatory, into Claus Benninghoven's pickup. At the observatory site, Broeker Erection again provided the crane to lift the telescope pier, equatorial head, and tube from the vehicles and place them in the dome.

The observatory was already prepared to receive the telescope. A concrete pier had been placed and trued for the cast-iron pier. As a form for the pier, we had used a 36-inch-diameter concrete culvert. To align the bolts, Bob Carhoff, Claus Benninghoven, and Jim Hilkin calculated true north and made a tem-



Opposite: The 12-inch lens after it had been reinstalled in the polished brass tube. The declination axis; note pick-off rings to transfer power to three motors on the telescope. The tailpiece and four-lens turret. Above: The objective of the telescope seen through the open dome slot. Right: Gleaming tailpiece proclaims the maker: Alvan Clark & Sons Co.

plate to hold the correctly aligned bolts. When we cast the pier, the bolts were installed in the template, the template placed atop the form, and the form was filled with concrete.

With a 10-ton flatbed pick crane, the pier was lifted off the floor of the observatory and placed on the pier base. The equatorial head was then raised to the top of the pier through the slot in the dome and also bolted into place. The polished 12-foot 4-inch brass telescope tube was then lifted into position with nylon slings. Dave Bachtell bolted the cradle assembly to the equatorial head. The focuser, objective lens, and counterweights were reinstalled and the entire assembly was balanced.

We tied ropes to both ends of the tube for temporary declination adjustment because the electric power had not been installed. As the installation was complete except for the final alignment, club members enjoyed the "first light" the telescope had seen in nine months. We completed final alignment of the optics and instrument to the celestial pole later at our leisure.

The Southeastern Iowa Astronomy Club is now undertaking the restoration of a 1931 J. W. Fecker refractor of 8-inches aperture that had been mounted atop the home of John H. Witte until October 1987. The telescope has a triplet objective and a three-eyepiece turret. It was donated to the Des Moines Conservation Board for use at the John H. Witte Observatory by Charles Rucker. The work on this telescope is now nearly finished and the telescope has already seen "first light." Although years of neglect harmed the drive system, the restored 8-inch Fecker will make a useful addition to the Witte Observatory as a hand-guided instrument.

Southeastern Iowa Astronomy Club
P.O. Box 14
West Burlington, IA 52655

Claus Benninghoven
421 S. Marshall St.

Jim Hilkin
420 N. 4th St.

Jim Blair
610 Walnut

Duane Gerling
1706 Mt. Pleasant St.

David Bachtell
Marion Bachtell
1901 South 10th Street
Burlington, IA 52601

Designing a YOLO Telescope

It has been twenty-four years since Arthur Leonard presented the unobstructed Yolo reflector, and yet the Yolo has not been as popular as it should be. I believe there will come a day when the Yolo scope will be very popular.

This instrument has not reached the place that it deserves because very little has been written about it, the advantages it has over other telescopes have not been fully documented, and a guide for its design and fabrication has not been published.

The Yolo telescope is an instrument mainly for observing the Moon, planets, and double stars. Its main feature is that it provides an unobstructed aperture in which a secondary does not degrade the image contrast and resolution. The Yolo optical system has the potential to provide excellent images over relatively wide fields.

It is true that the schiefspiegler telescope, which is also an unobstructed reflector, is easier to make than a Yolo. However, in order to have a good image, the focal ratio of the schiefspiegler optical system must be about 26, which results in a rather slow system. Three spherical mirror unobscured systems like the trischiefspiegler can be designed to have lower f/ratios. However, more work is involved in making and maintaining a third mirror, there is an increase in alignment difficulty, and there is slightly less contrast due to a third surface.

These facts make such systems less attractive to consider as an alternative. Other aspects to take into account when comparing unobscured systems are: image plane tilt, telescope maintenance, instrument size and portability for a given aperture and focal ratio, and the relative position of the observer in actual telescope use.

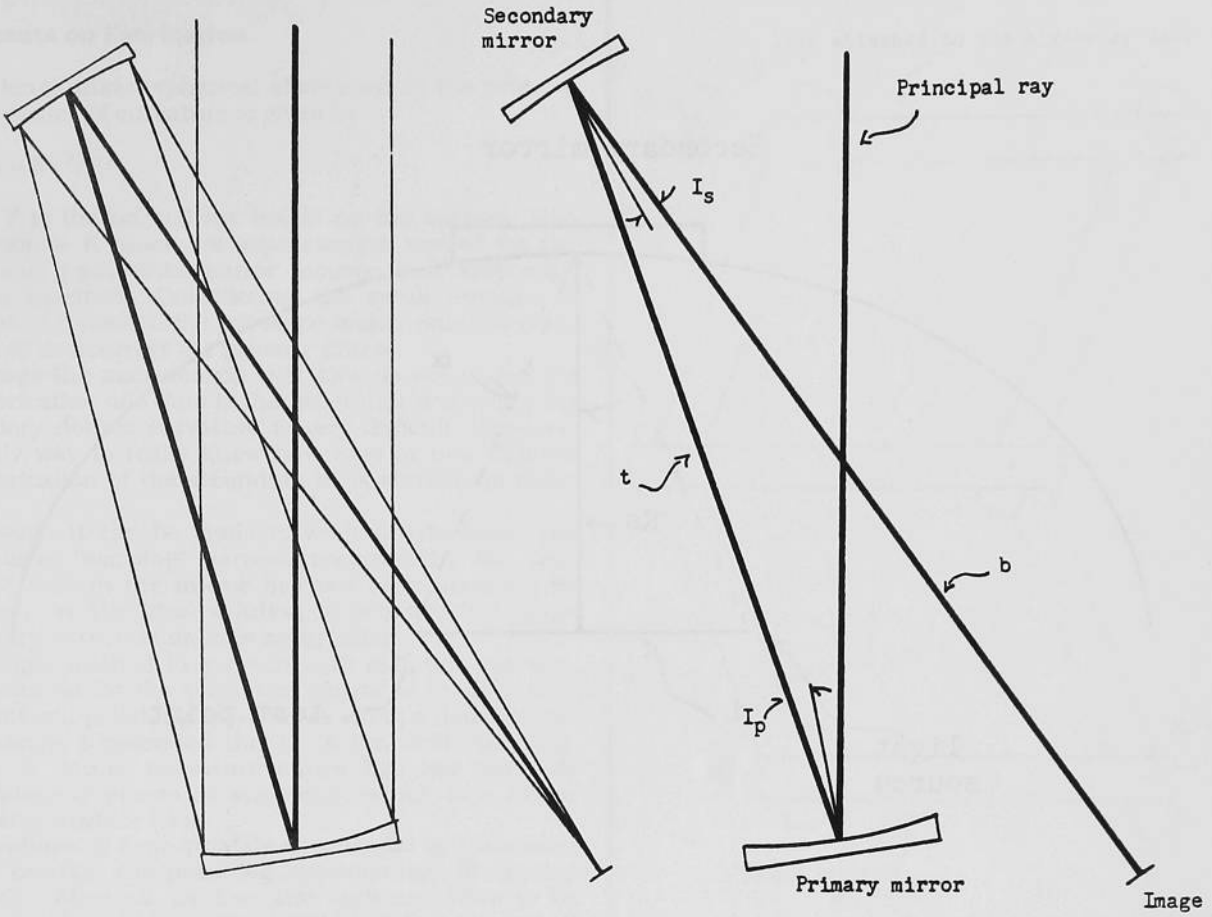
In its simplest version the Yolo optical system uses a spherical primary mirror and a secondary with a surface of double curvature to correct the on-axis astigmatism. The tilt of the primary is used to place the secondary out of the incoming light beam, and the tilt of the secondary is used to correct the on-axis coma.

These on-axis aberrations arise as a consequence of the mirror tilts, the latter can be canceled out but the former must be corrected by generating an oblate ellipsoid section on the smaller secondary.

In addition, spherical aberration can be corrected by making an axially symmetric hyperboloid primary. Then it is possible to design a 6-inch f/10 Yolo performing over a field of view 0.5 degrees better than an f/5 Newtonian of the same aperture. This would be the slowest design recommended for a 6-inch Yolo in which no field correction is considered.

The performance of a Yolo can be significantly improved if the tilt of the secondary is used to correct linear astigmatism and if the asphericities of both mirrors are used to correct on-axis astigmatism, coma, spherical aberration, and linear coma. This correction, however, increases the fabrication difficulty. Linear coma is the usual coma of a Newtonian telescope that increases linearly as a function of the field of view; linear astigmatism increases over the field in a manner similar to linear coma.

It is a fortunate circumstance for telescope makers that the image plane tilt and image anamorphism of a Yolo are quite small for most practical systems. This is so because the contributions of each mirror tend to cancel each other and because their radii of curvature are comparatively long.



The Optical Layout and Notation Used to Describe the Yolo

Design Formulae for a Yolo

The first step in designing a Yolo scope is to decide the primary and secondary apertures Φ_p and Φ_s, and their radii of curvature R_p and R_s. Then the tilt of the primary is calculated, that is, the angle of incidence of the principal ray to have an unobscured light path. It is given by:

$$I_p = (\theta + \arcsin((\Phi_p + \Phi_s)/2t))/2 .$$

where θ is the desired field of view in degrees and t is the mirror separation measured along the principal ray. (See below for a relation giving t.)

The angle of tilt of the secondary mirror, that is, the angle of incidence of the principal ray to correct on-axis coma is given by:

$$I_s = \arcsin((\varepsilon^2 \sin(I_p))/(\kappa^3 (1+2\varepsilon/\kappa))).$$

where

$$\varepsilon = R_s/R_p$$

and

$$\kappa = \Phi_s/\Phi_p.$$

Note that I_p and I_s are half the principal ray angles of deviation. The ratio R_s/R_t between the short R_s and long R_t radii of curvature of the secondary mirror to correct on-axis astigmatism is given by:

$$R_s/R_t = 1 - ((\varepsilon/\kappa^2)\cdot\sin^2(I_p) + \sin^2(I_s)) .$$

The primary K-factor to correct spherical aberration is given by:

$$\text{K-factor} = -1 - (1+(2\varepsilon/\kappa))^2 \kappa^4/\varepsilon^3 .$$

The primary focal and secondary focal lengths are given by:

$$f_p = R_p/2\cos(I_p) ,$$

and

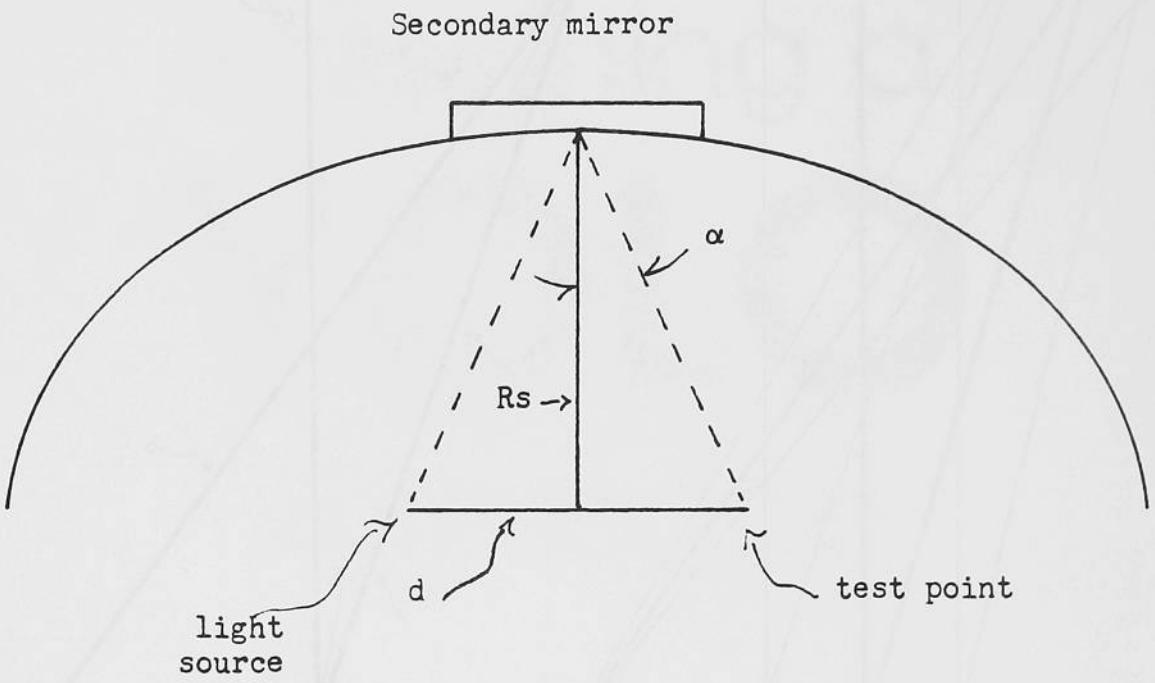
$$f_s = R_s/2\cos(I_s)$$

and the effective focal length is given by:

$$F = 1/((1/f_p)+(1/f_s)-(t/(f_p f_s))) .$$

The mirror separation is given by:

$$t = (1-\kappa)\cdot f_p .$$



Configuration Used and Notation for Testing the Secondary Mirror

The final secondary diameter, to have an unvignetted field of view, is given by:

$$\Phi_s + t \cdot \tan(\theta).$$

Note that t depends on $\cos(I_p)$ and can be approximated by:

$$t \cong ((1-\kappa) \cdot R_p)/2$$

to start the calculations. The distance b from the secondary mirror to the image plane along the principal ray is given by:

$$b = F \cdot \kappa .$$

It is worth commenting that some of the equations are not exact, but they give an excellent approximation of the necessary quantities when the angles of tilt are small, which is the case for the Yolo system.

Design Example: Albert Priselac's Yolo

After the publication of "A Practical Yolo Telescope" (*S&T*, August 1988), Albert Priselac, an amateur telescope maker from Uniontown, Pennsylvania, brought to my attention the weird size I chose for the mirrors of the aplanatic Yolo telescope. He wrote: "Sometimes motivation is governed by certain situations, I think convenience is the one that counts. . . ." I appreciated the philosophy stated in his comment, so I decided to design a Yolo for him using standard 4.25- and 6-inch Pyrex blanks.

The radii of curvature of both mirrors were chosen to be 5,150mm. Thus, $\varepsilon = 1$ and $\kappa = (101 \text{ mm})/(151 \text{ mm}) \cong 0.67$. The secondary is actually 108mm in diameter, which allows the system to have an unvignetted field of view of 0.5 degrees for a mirror separation of 855mm.

The primary and secondary angles of tilt are:

$$I_p = 4.5°$$

and

$$I_s = 3.8° .$$

The long radius of curvature of the secondary is 5,245mm. The primary K-factor is K = –4.2, and its effective focal length is 1,547mm. The f/ratio of the complete telescope is 10.2, and the distance from the secondary to the image plane is 1,035mm.

For the design of other Yolo systems, it is recommended to minimize the angles of tilt and verify the optical layout by making a drawing to scale. For an 8-inch aperture Yolo the minimum recommended focal ratio would be 12, and for a 12-inch aperture the mini-

mum focal ratio would be 16.

Comments on Fabrication

The longitudinal spherical aberration at the primary mirror center of curvature is given by:

$$\Delta Z = KY^2/2R_p ,$$

where Y is the normal ray height on the surface. This correction is K times the aspherization needed for the equivalent paraboloid mirror (source and knife-edge moving together). Considering the small amount of glass to be removed, the telescope maker must be careful not to overcorrect the primary mirror.

Perhaps the main reason that TMs do not undertake the fabrication of a Yolo is the belief that producing the secondary double curvature is very difficult. However, the only way to really know how easy or how difficult the fabrication of the secondary is, is actually to make one.

Although it can be made to work satisfactorily, the mechanical "warping" harness proposed by Mr. Leonard to deform the mirror has not been accepted by amateurs as the ideal solution to produce the shape necessary to correct on-axis astigmatism.

A simple method to generate and maintain the surface required for the secondary mirror is to allow only translational polishing movements using a double four-bar linkage. I described this in "A Practical Yolo Telescope." A double curvature mirror has two mutually perpendicular planes of symmetry, which is a rather symmetric surface form.

This shape, if appropriately encouraged by constraining in rotation the polishing movements, will develop naturally. After all, professional opticians have to be very careful to reduce to a minimum the amount of astigmatism on their optical surfaces because there is no such a thing as a perfect mirror. TMs will find surprisingly little difficulty generating the Yolo secondary double curvature using a double four-bar linkage and polishing principles similar to the ones used in making standard mirrors.

The secondary mirror can be thought of as being part of an ellipsoid. It can be tested at its focii, which are separated by a distance d given by:

$$d = 2\ R_s \cdot \tan(\alpha).$$

The angle α is found from the relation:

$$\cos(\alpha) = \sqrt{(R_s/R_t)} .$$

For the design presented above:

$$\alpha = 7.7°$$

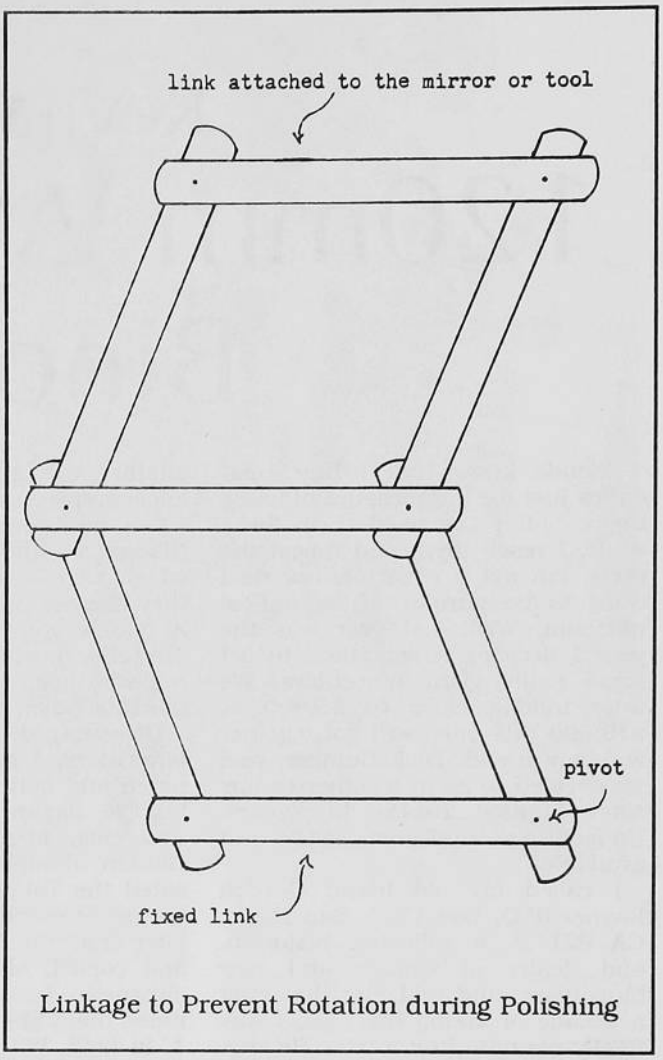
and

$$d = 1401 \text{ mm}.$$

It is worth mentioning that the Ronchi test is particularly useful for testing the secondary because it allows any surface asymmetry to be readily detected.

Final Adjustments

When aligning a Yolo the TM must be sure that the long radius meridian of the secondary coincides with the telescope plane of symmetry as defined by the mirror tilts. Assuming that this requirement is met, it may happen that after finishing and assembling the Yolo telescope some residual on-axis astigmatism, or coma, or both will be detected. These aberration residuals can be corrected by changing the mirror separation and the secondary tilt.



Linkage to Prevent Rotation during Polishing

One must remember that on-axis astigmatism increases as the square of the aperture and the square of the secondary angle of tilt, and on-axis coma increases linearly with the angle of tilt and cubicly with the aperture. Thus, on-axis coma is more rapidly varied by changing the mirror separation, and on-axis astigmatism by changing the secondary tilt.

I would like to thank Dean Ketelsen for his valuable suggestions.

Jose M. Sasian
446 North Norton Avenue
Tucson, Arizona 85719

Reference

Mackintosh A., *Advanced Telescope Making Techniques*, Willmann-Bell, Inc., 1986.

Revitalizing a 120mm World-War II Binocular

Friends know that I buy great optics just for the pleasure of using them. After I've used them for a while, I resell them and repeat the cycle. I'm not a collector, nor do I want to be curator of an optical museum. Well, last year was the year I decided it was time to get some really giant binoculars. We were talking close to $5,000 or $10,000 this time, so I got together with my friend, Dick Sumner, and we decided to go in together to buy some Fujinon 25x150 binoculars. No fooling around, just get the best available.

I called my old friend Gordon Rayner (P.O. Box 1742, San Diego, CA 92112), a collector, historian, and dealer of vintage and new binoculars, and told him that after a decade of taking his time, I was finally ready to buy a pair. He suggested I look through them first and said he would bring samples to the 1988 RTMC. Checkbook in hand and filled with anticipation, I flew to Ontario, rented a car, and drove up to Camp Oakes.

Gordon arrived later than I did and spent a chilly night sleeping between binoculars in his old VW microbus. The next morning, Gordon set up shop in front of the VW, putting a pair of used Fuji 25x150s on a heavy tripod and providing another tripod to test lighter stuff. The idea was that if I liked the used 25x150s, I could take them, or I could decide to buy a new pair. Used gear is cheaper, but you get chips, scratches, and no warranty. It was a good experience because I found I would not have been happy with the Fujis -- new or used. The apparent field is a bit small and the eye relief too short for me to wear glasses. Straight-through looking would have been a neck-breaking with these 65-pound binoculars. They're truly monumental! For another five grand, you get right angle eyepieces and a mounting.

Gordon brought a pair of used Nikons in the same size class, which were similar in quality, but they likewise had too little eye relief. Although you can buy new Fuji 25x150s, I wrote Nikon and they replied they don't import Nikon 25x150s anymore.

Discouraged with the 150mm binoculars, I lowered my sights a notch and noticed some less grand 20x120 Japanese binoculars with unfamiliar identification markings. Gordon thought the marks indicated the Tokyo Optical Company, the predecessor of Topcon. I learned later that the U.S. Navy captured and copied, almost directly, these Japanese binoculars and designated them Ship's Binoculars, Mark 1, in 1945. With 45-degree inclined eyepieces and conical barrels joined with a metal web, they have a pleasing appearance, shown in the accompanying photographs taken after I modified the eyepieces.

The interpupillary distance on these binoculars is adjusted differently than on the big Fujis and Nikons and looked more intriguing. More compact than 25x150s, the 20x120s weigh only 35 pounds -- half as much. Of course, I would also have to give up 30mm of aperture.

I had Gordon put them on the lighter tripod and began looking at distant pine trees. Because they had short eye relief, I removed my glasses. Two diopters of astigmatism make clear views impossible but do not preclude critical testing.

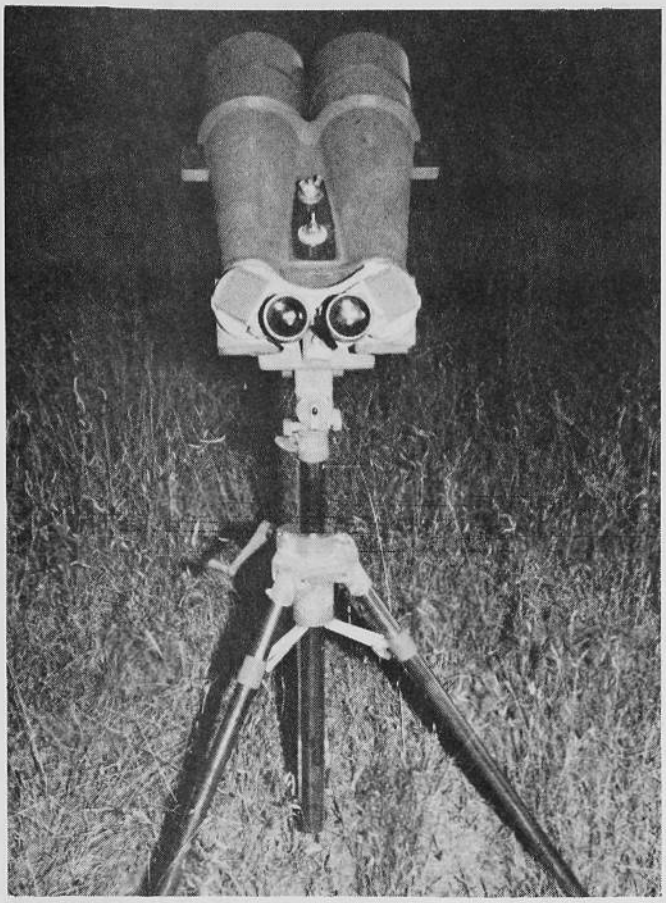
I was instantly taken with their wide 60-degree apparent field, and I reveled in the comfort of viewing with 45-degree eyepieces. They're a perfect compromise for viewing objects from the zenith down to the horizon. I could tell that whoever designed these 20x120s knew his stuff!

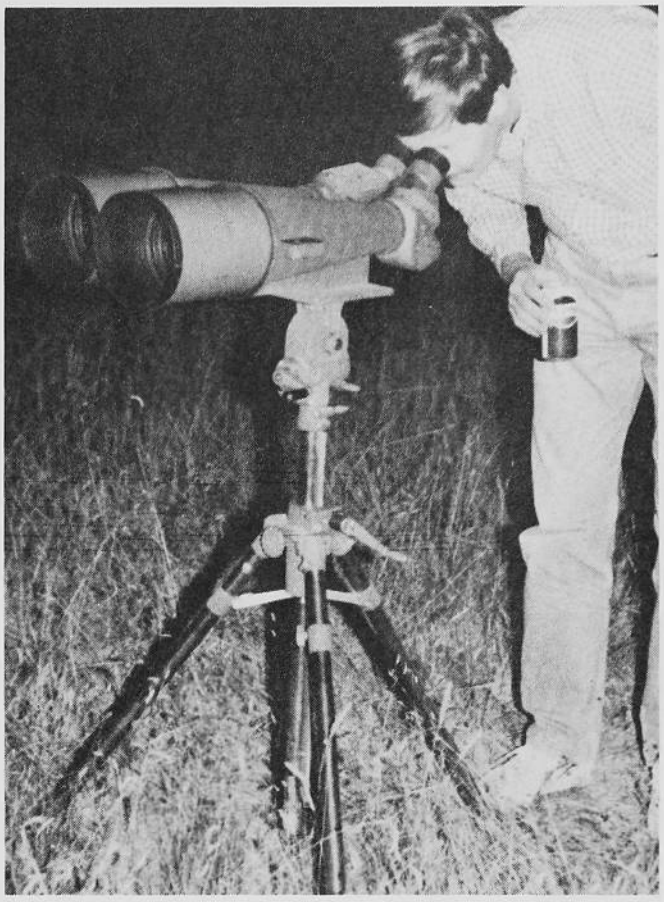
Although the eye relief was only 13mm, clearly not designed for eyeglass wearers, the optical aberration balance was very good. They have lateral color and a colorless, distinct field stop. By turning them around and looking into the objectives, I could see the optics were meticulously and thoroughly baffled, something rarely found in modern binoculars, regardless of price and manufacturer.

At this point I could see just two drawbacks to this pair of binoculars. First, in order to obtain the highly desirable 45-degree inclined eyepieces in this particular configuration, they had to be using roof prisms, which generally give an imperfect images. They show a diffraction spike. Worse yet, there's an inherent loss of contrast when the roof is unsilvered, as would be the case here. But even more important, the lenses, which were made before or during World War II, were hazy.

The pivotal issue was whether I could restore their clarity, for I was so impressed with the overall design and quality that I was willing to tolerate the roof prisms. Besides, the problems with the prisms can be solved by silvering their roofs. I asked Gordon if he would let me buy them contingent upon inspection by professionals in Tucson to see if it would be practical to restore them. He agreed, and my friend Derald Nye drove them back to Tucson for me.

Derald helped me build a mount and I set about testing them. The Moon looked great; stars were round, sharp, and properly achromatic in the axial region, which I could see wearing my glasses at night to get a critical impression. I could also substantiate that the





Two views of the 20x120 Japanese World War II binocular refurbished as 18x120s with long eye relief to satisfy people who wear glasses.

field quality was properly aberration-balanced, indicative of a competent, fully optimized design. Using a flashlight, I could see haze on all the optics, including the prisms. The binoculars wouldn't be worth much unless we could fix this problem.

I asked Dick Sumner to look them over to see what he thought about keeping them in the first place. Mind you, this was no longer a joint project but mine alone because of the risk involved. He thought they had merit. I then took them to a professional optical shop, TORC, and made a deal with the owner (and friend) Joe Appels. I would pay him to take the binoculars apart and clean all the elements for me. Then I would pay him to put it all back together again. I hoped this would not be a big deal. Wrong!

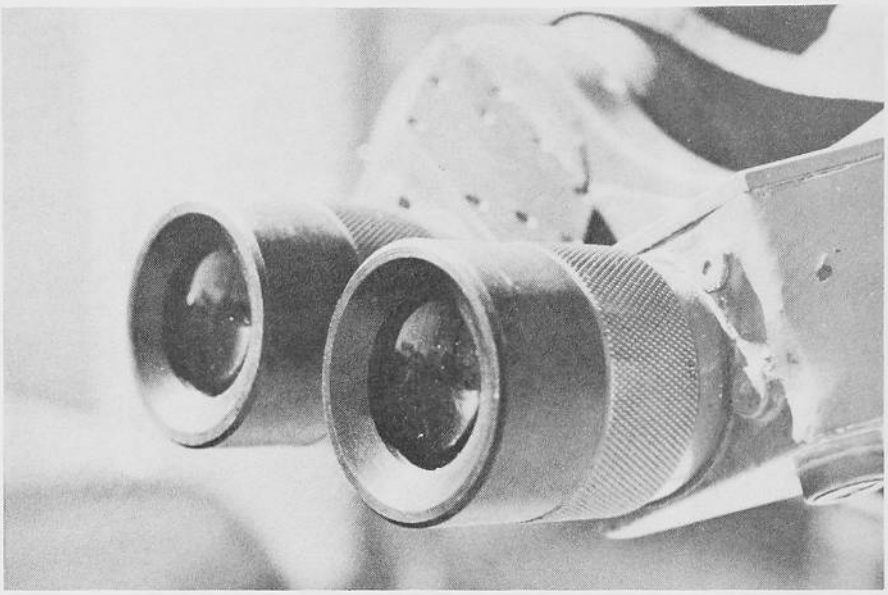
As he took the optics out, Joe rubbed them lightly with a soft cloth to see if the grunge would come off. To my dismay, the coatings came off! Apparently these binoculars use old technology, soft coatings that cannot be handled. We would have to remove all coatings with cloth, calcium carbonate, and water to avoid scratching the underlying glass and completely recoat all the elements, including the prisms. If we didn't, we'd get a net transmission of perhaps 50 percent -- a waste of big binoculars.

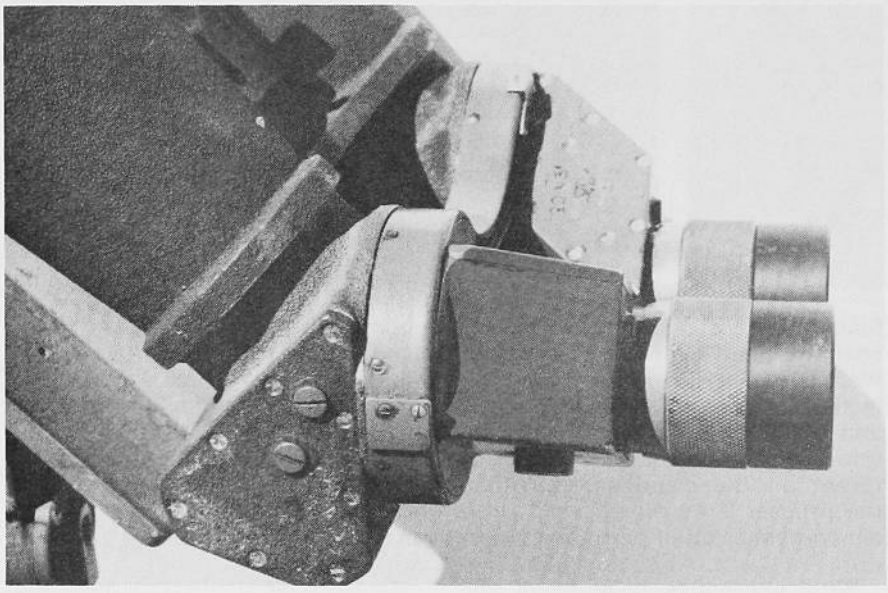
With misgivings because of the growing cost of restoring them, we carried on. To my delight, the underlying glass all turned out to be unblemished; it looked as fresh as the day it was polished half a century ago. Apparently the decaying coatings protected the glass. Don't rely on this to happen because it probably depends on where the binoculars are stored.

Evaporated Metal Films of Ithaca, New York, (advertisers in this magazine) antireflection coated all the lenses and prisms and silvered the roof prisms as well for only a couple hundred dollars. We did get a chip, but things could have been worse. With old optics, you hold the coater blameless and eat your loss if disaster happens.

From the outset I had decided that I would redesign the eyepieces to give 23mm eye relief. This would allow me to wear glasses. I would have Joe Appels make the new elements, and get a local machinist, Jim Steen, to modify the old eyepiece cells. This wouldn't be cheap, but by now I was dreaming of making this the best binocular anyone had ever owned. But first I had to understand the design before I could modify it.

As we took it apart, I measured the objective to have a 600mm focal length. This meant that the eyepiece focal length was 30mm to give 20x. This could also be determined by measuring the field stop and knowing the apparent field of the eyepiece. The total design is straightforward. The objective is an airspaced f/5 doublet. The image is rotated 180 degrees and deviated 45 degrees with an unsilvered Schmidt roof prism. The interpupillary distance (IPD) is established and adjusted with unsilvered rhombic prisms. A field stop contained a reticule in one eyepiece, and I removed and compensated for it. Both the objective and the eyepiece are separately parfocalized with this reticule, which is a bit of a problem unless you save all spacers and shims when you disassemble things. Finally, we have a five- ele-





Rear and side views of the custom long-eye relief 18-power eyepieces on the 120mm binocular. These are the original barrels, but new lenses.

ment eyepiece.

We learned the prisms were made from a borosilicate glass like BK7 by measuring them, weighing them, and calculating their specific gravity. Owing to the f/5 long focus objective, the exit pupils are round. The squarish exit pupil that occurs when binocular objectives are too fast occur when low index prisms cannot provide sufficient total internal reflection without silvering the hypotenuse. Even barium crown prisms won't suffice if the objectives are too fast or too short a focal length.

Collimation is achieved by decentering the objectives in adjustable eccentric cells, which requires that the objectives be free from coma. However, they are not free from axial color and spherical aberration but must have just enough to compensate for the prisms and eyepiece.

Badly designed (or "kludged") binoculars have fully corrected objectives, so the prisms overcorrect the axial color and cause a spurious blue glow around all bright objects. The eyepiece, on the other hand, must correct the lateral color and coma of the prism and the astigmatism from the prism and objective lens. Because of this, eyepieces that are designed to stand alone, such as astronomical oculars, make bad binocular eyepieces. This is why you shouldn't modify binoculars by adding astronomical oculars -- they won't work right. An unfortunately large number of binoculars in the astronomical marketplace appear to have been "designed" by unskilled persons capriciously mixing objectives, prisms, and eyepieces that are clearly unrelated to one another.

Because cost was an object in this exercise, I computed three-element long-eye-relief eyepieces with lathanum crown glass. The opticians had already started making them when Gordon Rayner surprised my by sending me U.S. Navy drawings on the Mark 1 20x120. These showed that I had made correct assumptions about the complete design, but raytracing revealed their five-element design was superior to my three-element design because its reduced chromatic variation of distortion, which has to be balanced with residual lateral color, results in a more color-free field of view.

This subtle point set a new standard for me. I redesigned the eyepieces using four elements, each a distinctly different optical glass. As with the Navy design, spherical aberration of the pupil was deliberately reduced. The final design is a completely unsymmetrical "Plossl"-type eyepiece that squeezes a lot from so few elements.

I reduced the power from 20x down to l8x in order to improve the quality over a 3-degree real field of view, which is the same as in the original. Figure 6 shows the original U.S. Navy eyepiece and my substitute with 23mm of eye relief. The apparent field is now about 54 degrees; the exit pupil is 6.7mm compared with the original 6.0mm. There is much discussion about what an optimum exit pupil should be. I believe not less than 6mm nor more than 7mm is still optimum for a forty-seven-year-old person.

You can measure your own pupil, as I did, with a red flashlight and a plastic metric ruler. Illuminate your eye with the red light in the dark, put the ruler close to your eye, and look at a mirror. You can also have a friend measure it for you. It's easy with blue eyes, harder with brown. This might be fun to try at your next star party.

What`s the big deal about a big exit pupil on the binocular? The deal is that although the apparent brightness of stars and other point-like objects depends only on the aperture and quality of your binoc-

ular, the brightness of extended objects depends on the diameter of the exit pupil. The majority of Messier objects, perhaps our main source of interesting subjects, are extended objects: gaseous nebulae, as in Orion, or spiral galaxies, as in Andromeda. My viewing experience unambiguously indicates that large pupil binoculars produce the most dramatic views. After you have a bright image, the next step is to make it bigger, which is where aperture comes in.

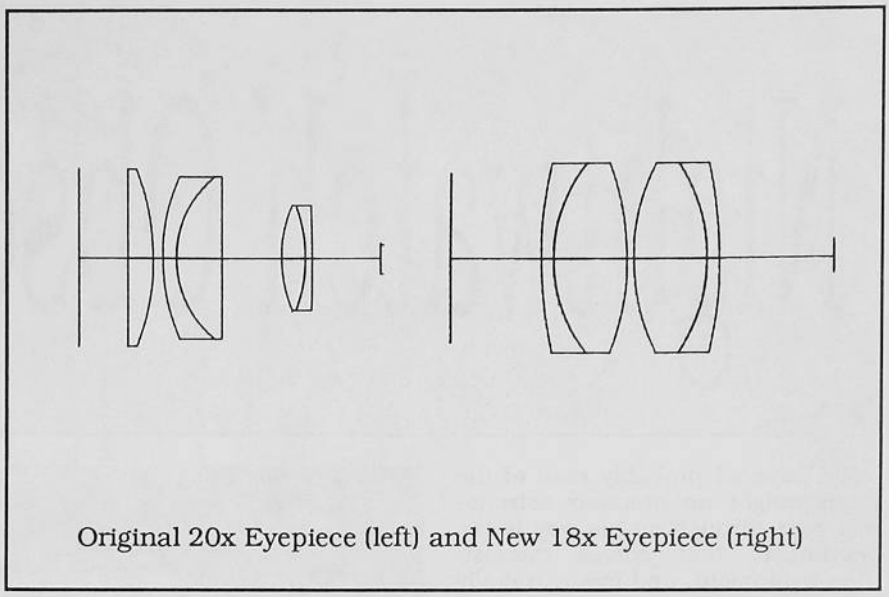
After considerable effort, we got the recoated optics back together. The new eyepiece elements were coated and assembled in nicely modified cells with black ABS plastic eye caps that avoid clicking and scratching spectacles, shown in the accompanying photos. I aligned the prisms visually, trying to reconstruct what original shims had done, and collimated the objectives by looking for identical images, relative to the field stops, in each eyepiece when looking at a mountain.

You get interesting effects when you do this on nearby objects, for then the field stops show parallax against a star field, and the stars seem to be lying behind the field stops rather than being framed by them. This method of collimation is proper if you have no error in image rotation (the probability of which is low if you put things back pretty much the same as they were before you took them apart), but I got some small aberration residuals due to imperfect prism alignment.

Originally I intended to refinish the exterior of the binoculars to make them "ship shape," but decided to let that lie for a while. They come with retractable sunshades, so if you aren't careful, they won't slide easily if paint builds up.

I borrowed a small but sturdy tripod of a beautiful design that seems unavailable from any camera store today, from the optical shop. It features rack-and-pinion elevation adjustment. Your binoculars can be out of balance with this tripod and yet will not fall. The center of gravity changes when you adjust altitude so sometimes the binocular is nose-heavy and sometimes it is tail-heavy. We made an adaptor that makes it balance at about 60 degrees. Someday I would love to find a good military-surplus binocular mount.

I'd actually snuck a look before I had the binoculars fully collimated and mounted. Dean Kettleson and I drove down to the dark skies south of Tucson on a moonless night, and we laid the binoculars on a towel on top of my station wagon. Comparing them with Dean's Nikon 10x70s and my Fuji FMTSX 10x70s, it was immediately obvious that the 18x120s completely outclassed the smaller binoculars. Considering that even the largest Messier objects are less than 3 degrees in size, you can see why. The field of the 18x120 is 3.0 degrees. Thus, the Andromeda Galaxy almost fills it. There is almost no danger that you could have "too big" a pair of binoculars, something I worried about a few years ago.



Original 20x Eyepiece (left) and New 18x Eyepiece (right)

Now that it's collimated and on a satisfactory tripod, I've had further enjoyment with the 18x120 binocular. I own a small lot in Sedona that still has fairly dark skies. I took the 18x120s and a good pair of 20x80s with me a few months ago when the Moon was down. After spending about an hour A/B-ing the two binoculars, it was clear to me that there's no reason to use a 80mm binocular if you have a 120mm binocular. There is no comparison in the richness of the views you get. Aperture makes an huge difference.

I spent the next two hours awe-struck, scanning the Milky Way with the 18x120s while comfortably seated on a lawn chair. Thanks to the 45-degree inclined eyepieces, this was with negligible strain! I might also add that the long eye relief of the new eyepieces is very comfortable for me, wearing glasses, but non-glasses-wearers report no problem with the 23mm eye relief. The field stops, always comfortably in the field of view, sharply frame the image, which is an elegant touch. Many binoculars have so little eye relief that you must strain, even without glasses, to see the field stops.

I don't know how many of these large binoculars have survived the ravages of the junkman. I suspect by now all of them, due to sheer age, need some refurbishment. If you don't wear eyeglasses, then cleaning and recoating the original optics would yield a binocular much cheaper than mine. Replacing the original eyepieces with new ones merely to gain an additional 10mm of eye relief cost me $1,000 on top of the $2,000 I paid to Gordon. My final investment in this project was close to $5,000. That's the price of a new pair of basic Fuji 25x150s. For many people the money might have been better spent buying those instead, but because I wear eyeglasses, the 18x120s are a better choice for me. The inclined eyepieces tip the scales even farther.

If I'd known at the outset it was going to cost this much, I doubt that I would have started. On the other hand, I learned first-hand an incredible number of interesting things about binocular optics, baffles, mechanical design, and assembly. Furthermore, I now have a first-class, customized 120mm binocular with unparalleled eye relief and overall image quality. And when it comes to viewing the stars with it -- WOW! Nothing smaller compares, and I can only imagine what still larger ones would do.

R. A. Buchroeder
Box 30266
Tucson, Arizona 85751

Nightwatch Observatory

We have all probably read of the many stages an amateur astronomer goes through on his way to the poorhouse: first comes interest, then equipment, and finally a really dark site.

My interest goes back quite a few years. My first telescope, a 4-inch spotting refractor I bought after the war, still occupies a spot in my study some forty years later. I can still remember scanning those dark skies of yesteryear.

Equipment is easily obtained today, much like cars. You soon finalize on that perfect instrument along with some "extra stuff," which you chalk up to the learning curve.

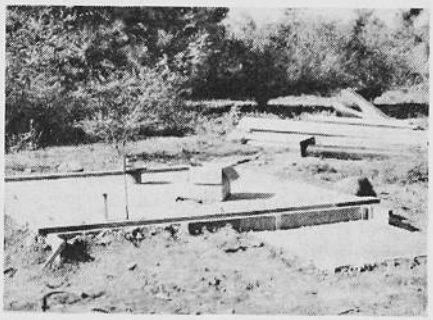
Finally comes the site. To get the skies I remember as a kid, I drove about an hour east. The elevation is 5,200 feet and on the good weather side of the Sierra-Nevada Range.

This is a fair haul, especially if you have sizable equipment with accessories. Then there is the set up and break down. Larry Myers, a good friend and associate, shares star time with me. He also shares the inconvenience of travel. Oh, the nights we set up and the hours we waited convincing ourselves that the sky was getting better!

We decided to build observatories. With camera and film in hand and the equipment always ready, we figured there would be no more sledding our instruments through the snow and no more digging our piers out of waist-deep snow.

We planned to build two observatories. Mine we built last year, and Larry's we built this spring. Permits were gathered, the dome was ordered, and we were on our way.

My story-and-a-half-high building is 8 feet square. Six yards of concrete went into the slab and pier support. The walls are 2x6s on 12-inch centers covered with 5/8-inch sheathing. The first story is insulated. The roof is two pieces of 14-gauge galvanized steel, flashed to the outside of the building. Atop it all is a 2.5-meter dome.



No more than a slab in this this picture, Nightwatch grew to completion in a week's work. The pipe pier shown behind turned out too small.

The first floor contains storage, a bookcase, and a nice snug bunk. I access to the telescope deck with a fold-down attic ladder. This deck holds two desks, storage, and the reason for it all: the telescope.

After considerable planning, and the help of Larry and Dick Morasso, the project took a total of six days to complete, less the finishing touches. Last year we even gave up RTMC for construction. It rained one day and snowed another, but it was fun. I look forward to many nights gathering starlight with my camera, and the convenience of being able to pop in anytime.

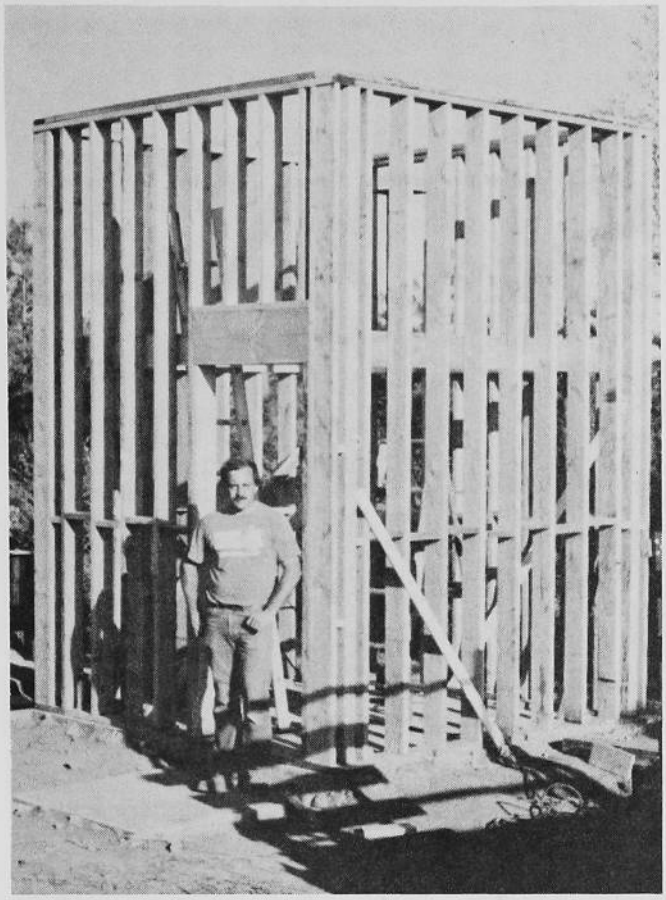
Digging the foundation is one part nobody looks forward to. You just know that under that soft carpet of needles you will find the stone that will force you to move to a different location. I only found one two-man stone. The footing is 18 inches wide on an average, and 2 feet deep with two #4 reinforcing bars. We used 2x10 rafters as above-ground forms, producing an average slab thickness of 9 inches and included 6-6-10 wire reinforcement. The pier support was poured with the slab. The support reaches a depth of 4 feet and is 3 feet square. The completed foundation weighs some 26,000 pounds.

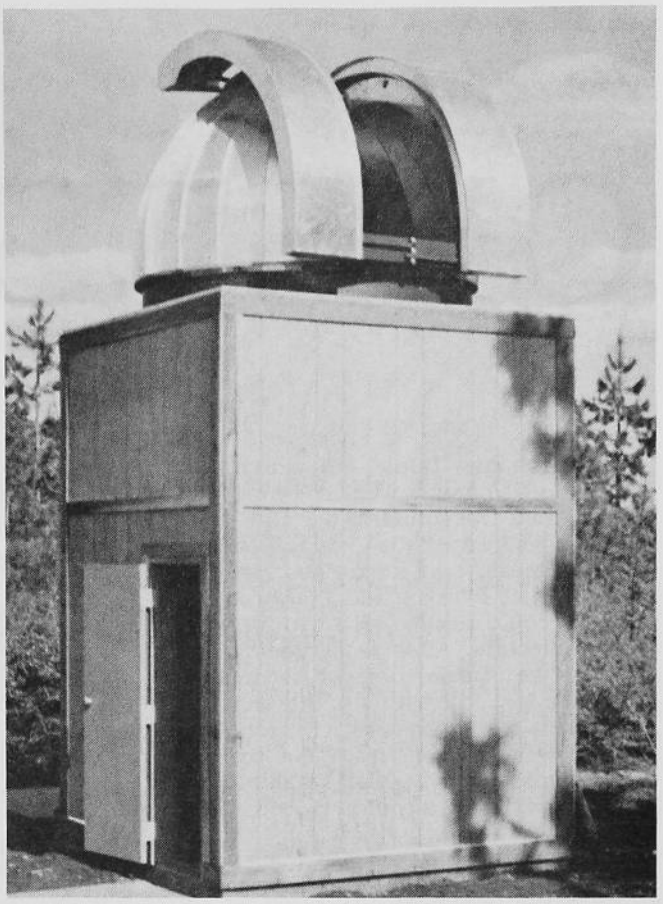
The pier itself is 6-inch pipe with tension rods. After the pier was in place, we raised a 3-foot square of concrete 3 feet above the slab around it. Even though there are some vibrations from the column, there is no deflection problem. I had read that filling the column with sand would dampen the column and cure the vibration. This may be true of large diameters, but not for small diameters. The sand fill was a mistake and will be remedied this year by removing the sand and replacing it with concrete.

As mentioned earlier, the building was framed with 2x6s on 12-inch centers. Each wall has three 3/4-inch J-bolts embedded into the footing. At each of the four corners are hold-downs. These metal devices are fastened over the plate via the anchor bolts and then to a stud with two bolts. Because the building has a problem with the height to width ratio — it's 8 feet wide but 17 feet high — the hold-downs are there to prevent high winds or drifting snow from overturning the building.

The building's size comes from setting the roof ring of the 2.5-meter dome even with the side wall. This has worked out well and provides a nice 7-foot-square space inside.

The corner projections beyond the dome, what I call the roof's wings, are a problem when a few feet of snow builds up on them. By rotating the dome back and forth, we have found that the snow can be bulldozed off with the shutter projection. If I had it to do all over again, I would have used a 3-meter dome; the building's corners would





Tall and skinny — just an observing room atop a storage room. Framed-up structure uses 2x6s in the walls. The dome is a commercial 2.5m unit.

then be the same dimension as the roof ring diameter of the dome.

There are a lot of pros and cons to consider when it comes to covering the building. The basic choice is between roll-off or domed roofs. There could be the question of economics, but I've seen many home-built domes that did not cost any more than a roll back, so economics may not be as much of a problem as the effort involved.

I chose the dome for two reasons. First, I felt a dome would offer more protection from stray light when people drove up during the night (the site is shared). Second, a dome provides more protection from the elements. With a dome, dewing is no longer a problem, and a night spent inside the dome is very comfortable indeed. I find myself taking extra clothes off as the night progresses, whereas I used to put more on.

I do find it harder to find objects because orientation is a problem when you only see a slit-wide view of the sky. The other night I let a long exposure go into the dome for the first time. Because the dome had not blocked my guide star, I did not realize the interference until I stood behind the equipment to stretch my legs.

At first I began to build my own dome. It was constructed of two arches that formed the shutter opening and had a half-hexagon shape at the two sides. The roof was made up of two pie-shaped panels with a square panel in the middle. Good looking dome. It was very simple, yet still looked "domey."

But then I decided not to get into problems with the building department over something that was not in their book. They would have required a full set of comps and a stamp which would have cost two-thirds the price of a purchased finished dome. I decided to staple the buy-out dome brochures to my plans and save the effort.

Unfortunately, I chose "the other guy's" dome to replace the one I discarded. Assembly took most of one day. There were too many long bolts, not enough short ones. Most holes had to be reamed to get the fasteners in. The welds leaked when it rained. The dome-to-roof ring seal was a plastic-coated duck material designed to go under the skin (lots of luck!) and a drawstring to pull the roof ring. The shutter weather strip did not keep the rain out when the wind was up. If I ever do it again, I will investigate an Ash-dome.

All in all, I am quite satisfied with the project. The observatory is of sufficient size to be comfortable, yet cozy. At best, it is a two-man building. I think it was Ernest Ghann who said that the best size for boat is sufficient for one person, now and then two, but very crowded with three.

I do not miss the cold flow of air over my lap that rises up from the adjacent gully in the early morning. Nor do I miss the headlights turning into the site from some thoughtless late arrival. My charts are dry, as is my equipment when morning comes.

During my shoots, though, I do miss the cover of stars, the misty glow of the Milky Way, and old friends like fuzzy M13 and the soft light of M8 and M17. This is the price of a dome.

Phil Mattingly
5317 Terrace Oak Circle
Sacramento, CA 95628

The Making of

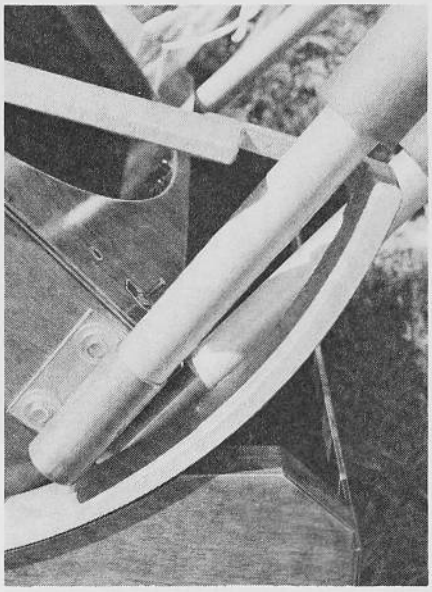
OBSESSION 2

You probably think I'm crazy. Why would anyone with a brand new 20-inch Dobsonian build a 25-incher? Well, aperture fever is a serious illness, and for me it's terminal. When I was a kid I always wished I could resolve M13 with my small reflectors. After *really* seeing some of the Messier objects for the first time last fall with my 20-inch Dobsonian (see *TM#35*), I went nuts. When I heard that Galaxy Optics was going to start making 25-inch primaries, I couldn't sleep. I had to have one.

Another reason I built Obsession 2 was to make some improvements to my original design and find out what the limits of the Dobsonian design really are. After Obsession 1, there were all those "if I had it to do over again" thoughts in the back of my mind. So on January 2 I started work; and because everything was still fresh in my mind, it only took four months to build the 25-inch f/5 Dobsonian I named Obsession 2. The overall design is the same as Obsession 1. However, many little things add up to make a big difference in total optical and mechanical performance.

Optics: It starts with the optics: John Hudek and Jerry Wilkenson at Galaxy Optics bent over backwards to fabricate a premium-quality primary for me. They made five 25-inch f/5 mirrors and sold me the best one — images are excellent with pinpoint stars — and put a 98 percent reflective silver coating on it. I hope to get three years of service from it before recoating. By then, hopefully, longer-lived enhanced aluminum will be available in this diameter. Delivery of the mirror was prompt: just seven weeks.

Mirror Cell: When a semitrailer pulls up with a 110-pound crate on a wooden skid, you begin to realize just how big and heavy a 25-inch mirror is. I beefed up the scope's structural components accordingly. However, the mirror cell is lighter and was easier to make than on Obsession 1 because I only used two "rungs." Turning my original cell design upside-down, I put in one rung for two upper collimation bolts and one rung for one lower collimation bolt and two off-center pins. The mirror is sling-supported as before.



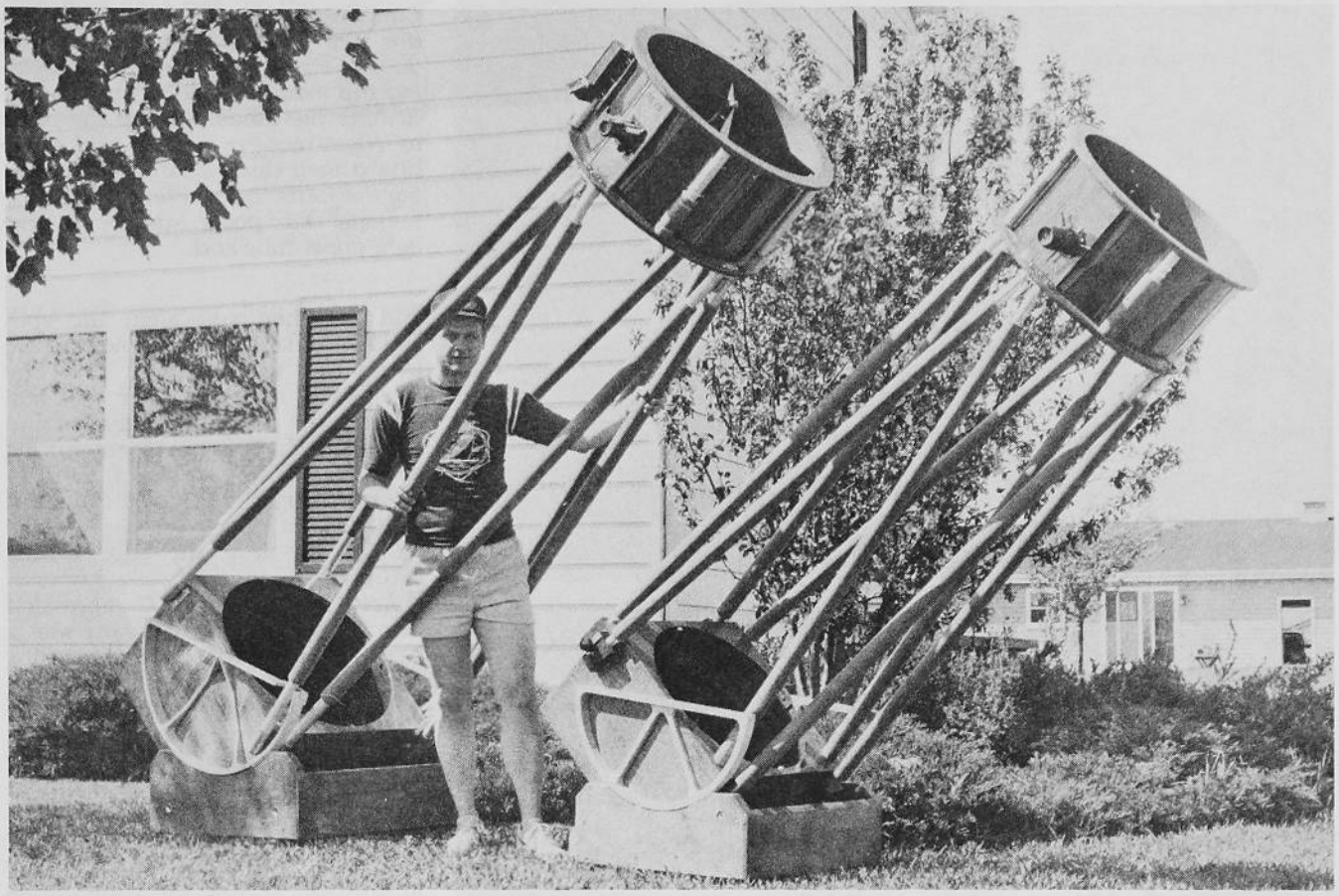
With a redesigned pole locking system and "wrap-around" cast-aluminum altitude bearings, Obsession 2 is extraordinarily quick to set up.

Cam poles: To reduce setup time, I wanted a fast way to attach truss poles to the mirror box. I got the idea from the cams used in telescoping golf ball retrievers, tent poles, and swimming pool cleaners. Put an off-center cam on the end of each truss pole, drop them into a short piece of tubing mounted on the mirror box, and twist. The cams work slickly and make setup and take down faster and more fun. They are also stronger. Although it sounds easy to fabricate these assemblies, it turned out to be tricky.

The cam is a stainless steel disc 3/8 inches thick and 1.5 inches in diameter, it has the same diameter as the outside diameter of the truss poles. Drill a hole to accept a 3/8-inch bolt 1/32-inch off-center through the cam. Into the ends of each of the eight truss poles, press-fit 1-inch-long stainless steel plugs with a threaded hole in them to accept the 3/8-inch bolt. This threaded hole is also 1/32- inch off-center. The cam should turn freely on the end of the truss pole.

So far it's all simple lathe and drill press work. Making the 4-inch-long stainless tubes that retain the poles is the tough part. The inside diameter of these tubes must be 1/64 inch larger than the outside diameter of the truss poles; otherwise you have a cam that won't engage, or worse, you'll have poles that stick up at all sorts of angles and make cage placement impossible.

Machining an inner diameter in such a small tube is difficult because most cutting tools won't fit, or there isn't enough strength running in more than a couple inches using a small tool. After receiving eight of these gems from a machinist, I thought I had it made. I didn't know welding a flat mounting plate on to the tubes would warp them to the point of uselessness. I had to go back and laboriously ream them out with a hand drill and #40 carborundum sandpaper. Next time I'd weld the plate on first, machine the inside diameter, and then cut off the end of the tube that rides in the chuck. To provide for a positive pole



Side by side, the two Obsessions look much alike. But lots of small improvements add up to better performance from the new telescope.

stop, I had a small lip machined into the bottom of each tube. The lip also provides friction so the cam holds still when the pole is twisted and locked into position.

Truss Alignment: After my article on Obsession 1 in *TM#35*, I received numerous requests for advice. It seems many TMs are bewildered by the split block alignment. Many are fearful to try a truss and submit to a solid tube assembly. The way I did it on Obsession 1 was ridiculously complicated. The following method is a much easier and more accurate way to do it.

Assume your mirror box is square and that the top edges all lie in the same plane. Draw a marking line down from the top edge and in from the side about where the block will be. Place a cross mark on all eight corners of the box at exactly the same place and drill a hole through each one. These marks and holes should be made on the sides of the blocks that mate to the box.

Now attach the blocks to the box with one wood screw (or a hex-bolt if you try my cam tube design) and tighten until just snug. Drop in two precut poles on one side and rotate the blocks until the poles come together equally up at the apex. Mark your block locations.

Do any angling in or out with shims. These shims should be the same thickness for all eight blocks, if you are a good carpenter. I needed to shim my cam tubes inward 1/16 inch over the length of the 4-inch mounting plate. I actually made all eight of the "wedges" from aluminum without ever looking at the scope.

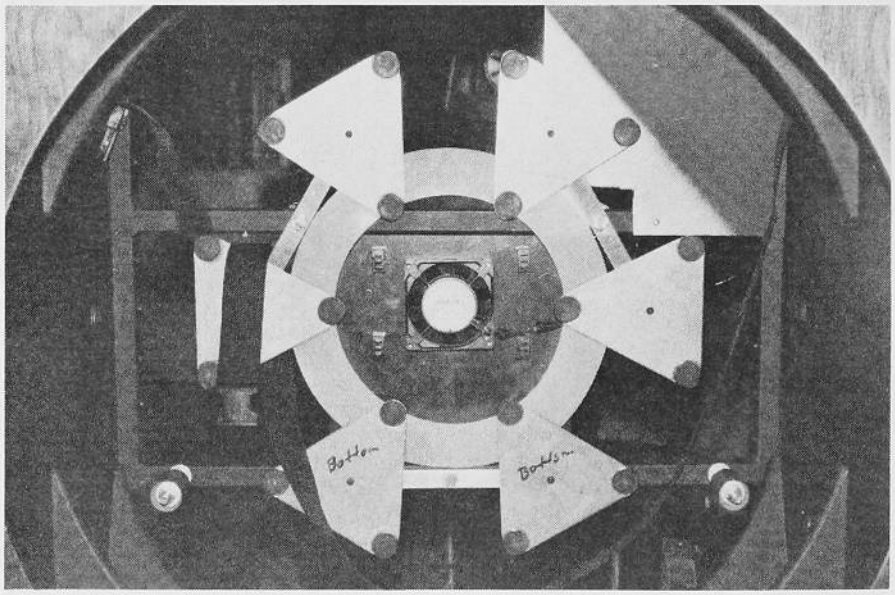
The shim thickness is the ratio between the difference in cage and box diameter to the distance between the cage and box. Apply that ratio over the length of the block or over the length of the mounting plate on the cam tubes. I attached and aligned all the cam tubes in two hours <u>without</u> the cage. I couldn't begin to do it with the cage because the assembly wouldn't fit in my garage!

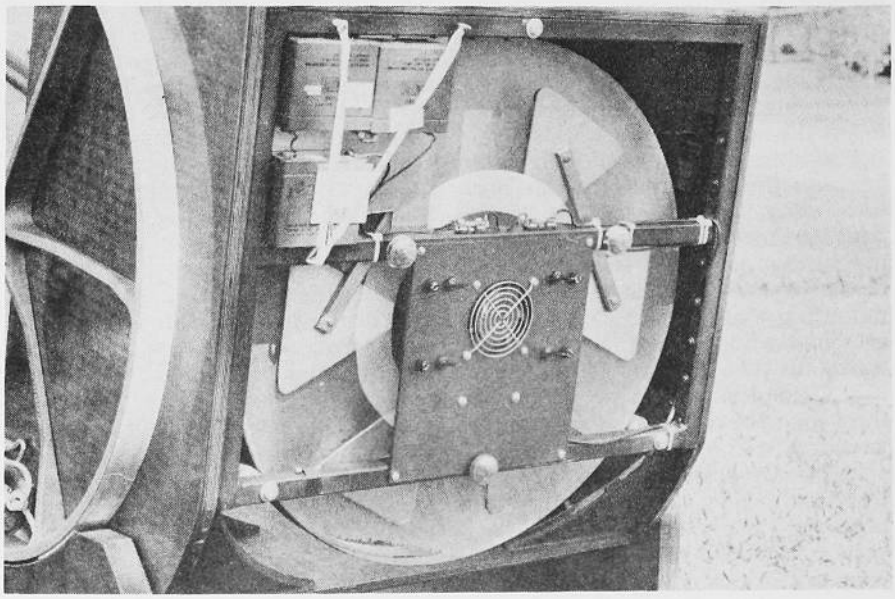
Pole Lengths: By now you are wondering how to determine the pole lengths. To do this, you'll need your optics, the finished cage, and your mirror box complete with flotation cell in place. Go outside and place the mirror box on its side with the primary in it on a large picnic table or a deck with a clear view of a *very* distant object. Line up the cage with the primary and roughly align the secondary.

Put an eyepiece in the focuser and move the cage back and forth along the optical axis of the primary until an image forms, sort of a "first light" in the daytime. Get out your eyepieces and try them to determine which cage to box separation will allow all of them to fall into the range of the focuser.

Now measure the distance from the corner of the mirror box to about where the bottom of a split block will go, up to the area on the cage where a pole seat will eventually attach to the poles. Write this number down. Add 2 inches and cut all the poles to this length. You can gradually reduce the pole lengths later and the truss will still work great. Don't try to guess and cut the poles to the exact length or you may end up ordering more tubing because you just can't get your focuser racked out far enough to focus your 12mm Nagler.

Don't repeat a mistake I made on both Obsession 1





Cams and tubes for the pole system are the trickiest element of the design improvement because welding the mounting plates to the tube distorts the tubes. Cutting the poles to length requires a large workspace and a very distant target for checking the focus. Locked firmly into their sockets, the poles support a very light upper tube end.

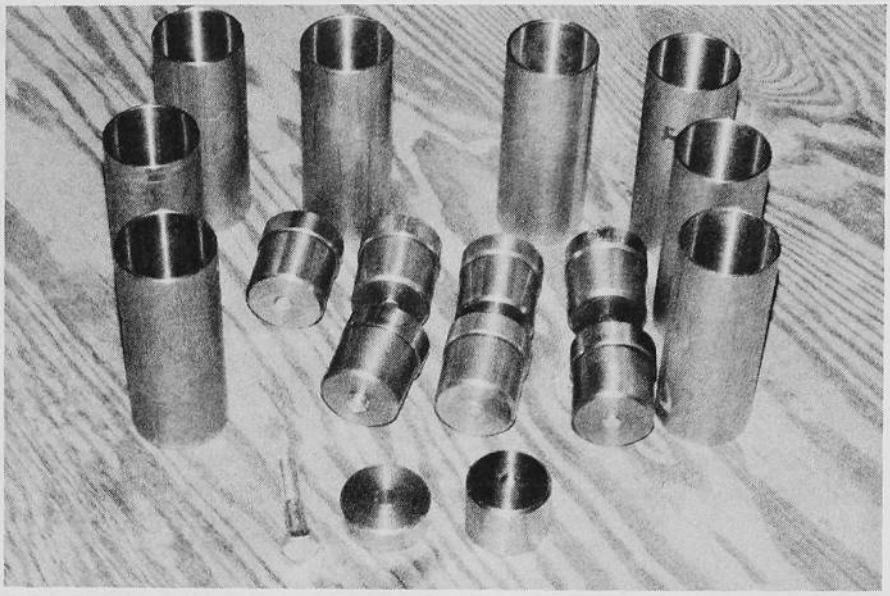
and 2. When you align the split blocks, make sure the pole tips are in contact at the apex. This way after final trimming they will still fall into the pole seats. I goofed and left an inch between them during construction so that after final trimming to length, the poles came out a bit too far apart, making it more difficult to drop the cage during setup.

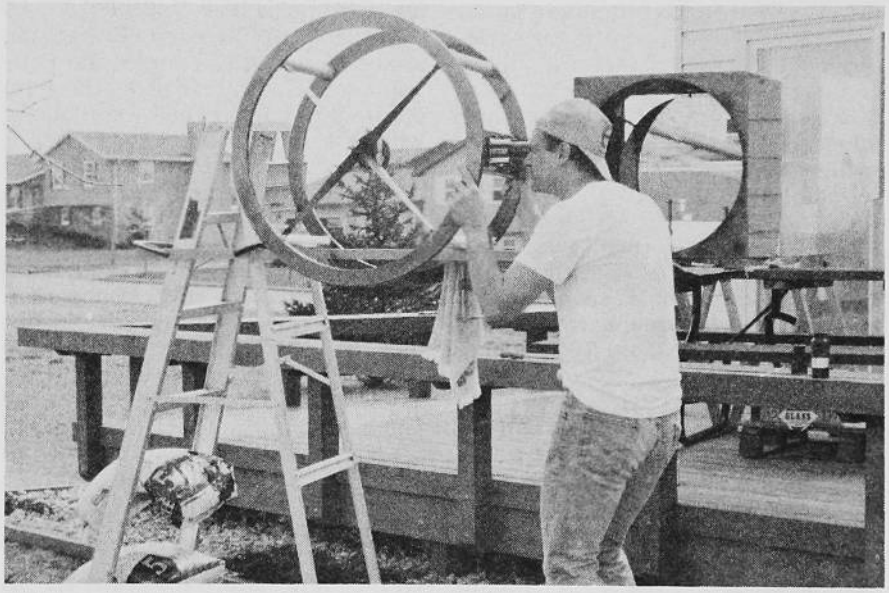
Azimuth Bearings: Compression flexure in the ground board was a headache in Obsession 1. Arranging the three azimuth pads 120 degrees apart and 10 inches out from the center pin gave optimum friction, but the rocker base flexed slightly under the weight. I've seen this in other large Dobsonians, too. It shows up as slight oscillation after letting go of the scope when aiming in altitude. Moving the pads out as far as possible so they run under the rocker sides, where stiffness is greatest, eliminates the problem, but then the scope is too hard to turn.

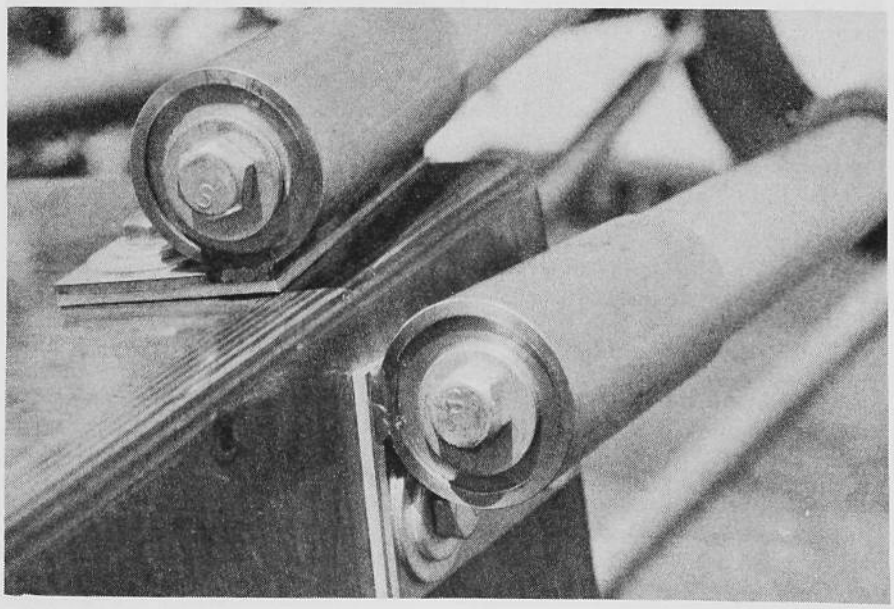
The solution was given to me by John Vogt, who exhibited a 24-incher at Stellafane (see *TM#31* for a picture of his telescope). He told me to place a small Teflon "washer" around the center pin on the ground board and shim it up a tiny bit. I tried this and it works great. By supporting part of the weight on the center pin where there is no resistance to turning, the pads can be placed out as far as possible. This eliminates flexure and is very easy to turn in azimuth. Be careful, though, because if you put in too much shimming the wind will blow the scope around or it will begin to pivot on the washer. Both conditions are undesirable.

Altitude Bearings: The cast altitude bearings are 32 inches in diameter and skirt the lower truss poles. It's nice having all the poles on the outside of the box. Assembly is faster and it looks better. Castings are fun because you can customize them to the desired function, allowing for more design freedom. I cast the pole seats in pairs. They

The floatation cell for the mirror is important because large, thin, high-quality mirrors need very uniform support. The system of levers and triangles is assembled on a sheet of thin plastic, then installed on the "tailgate" assembly mounted at the rear of the tube box. Batteries and a fan to blow air on it to insure that the mirror cools to air temperature.







are much stronger than if they were separate, and they prevent deformation of the lower case ring where the hitch pin sits.

Performance: As far as ease of assembly, portability, and mechanical performance go, I knew I made believers out of any skeptics in the Houston group I observed with at this year's Texas Star Party. Thanks to the pole cams, setup and take down are faster and easier than with Obsession 1. I must have run the setup and take-down drill a dozen times during the thunderstorms over the Prude Ranch. I think they actually got a kick out of watching how fast I could do it.

As for optical performance, I knew there would be an improvement going from a 20-inch to a 25-inch telescope, but I was still shocked by the difference. The images under a dark sky are as good or better than any of the astrophotos in Jack Newton's *Cambridge Deep Sky Atlas*. I must confess that the crisp star images from this mirror have spoiled me for anything less.

Obsession 2 is probably the largest telescope I'll ever want, and it's still one-person portable. I am comfortable using an 8-foot ladder to observe, and most deep sky objects still fit into the field of my 20mm Nagler.

As for me, I'm still an inexperienced observer and Obsession 2 is obviously more telescope than I can really appreciate. Jerry Wilkenson from Galaxy could see this. On our last night at the Texas Star Party, while he waited patiently for me to locate the Swan Nebulae, Jerry remarked, "This man does not deserve this telescope."

I got a good laugh out of that because it's true. But hey, I'm in hog heaven. I've got a lifetime of fantastic observing ahead for me and my family. I may be obsessed with building the things, but looking through them and learning the night sky is even better.

David Kriege
923 Stoney Road
Lake Mills, WI 53551

Building a High-Performance Newtonian Reflector

Ever since I heard a replay of the Orson Wells classic radio show "War of the Worlds." I've had an interest in the planet Mars. But I had never been in the right place at the right time with the right scope to get a good look at the Red Planet. By "right," I mean a planetary telescope with crisp, clean, high-contrast images.

Refractors are famous for their images, and my own experience with a friend's 4-inch and 6-inch refractors confirmed the conventional wisdom. But college students don't have much money to spend on things like refractor objectives, and I was looking for a scope that I could build with my normal crude technology of plywood, T-nuts, and a jigsaw.

I own, or "had once owned," a nice 6-inch f/8 reflector with a superb mirror. I thought about rebuilding it with a smaller than average diagonal. There was a problem with this: I had been keeping the scope in my parents' garage, and my mom had taken up using it. She would have KILLED me if I changed HER scope!

So one day I was visiting Tom Burns in Columbus, Ohio. Tom has a collection of optics that will turn any TM into silly putty, such as a 6-inch f/20 Tri-schiefspiegler with Wessling optics that just won't quit. So I put the question to Tom: What set of optics would be right for a low-budget winter project that would give great results on Mars?

Tom ducked back into his magic room and returned with a box. He mumbled something about Dick Suiter and him coming up with this combo. He had a 4.25-inch f/10 mirror, a super tiny 1/2-inch diagonal, and a 5-inch optical window. It sounded like a special, one-of-a-kind optics set, but it wasn't. Four-and-a-quarter-inch f/10 mirrors are common and cheap. Edmund makes the diagonal for $13 (Part #J32,271). The shocker was the window. It's from an Astroscan, coated on one side, and a steal at $13.50 from American Science Center or Edmund (Part #42638).

I ordered all the parts. Everything arrived quickly, but under the Foucault test the mirror (from Jaegers) showed a bad turned edge along with a bump in the center. I sent the mirror back with a sketch of its figure. Six weeks later they returned the same mirror, now a beautiful sphere.

I build my scopes out of plywood and normally use Dobsonian mounts. This, I figured, would not pose any problem. However, I anticipated some other problems. How would I mount the diagonal to the window? How would I make a cell for the window that would allow all the adjustments needed to collimate the optics?

I made a support for the diagonal out of 1/4-inch dowel rod. I cut one end square and the other at 45 degrees. I then glued the diagonal to the stalk with aquarium cement. After the glue set, I glued the other end of the stalk to the window. On the outside of the window, I glued another piece of 1/4-inch dowel an inch long. This gives me a way to rotate the window, and therefore to rotate the diagonal, for collimation. Four sets of push-pull screws allow me to tilt the window and the attached diagonal. The window cell is made out of three pieces of 1/4-inch plywood.

In a design like this, it's necessary to make the focus as close to the tube as possible. This means the distance between the eyepiece holder and the primary is critical. You have to know things like where the focus of your eyepieces is. I was saved from a lot of these problems by Tom and one of his rules of TMing: "Slop, slop, slop, and more slop."

Tom's idea was to build the tube of the scope about 2 inches too long. The primary mirror cell has one center bolt holding the cell down, and three adjustment bolts pushing the cell away. I simply used extra-long bolts. When the scope was completely assembled, I plugged in the eyepiece, "rough" focused by moving the primary mirror in and out, and left the fine focusing for the eyepiece.

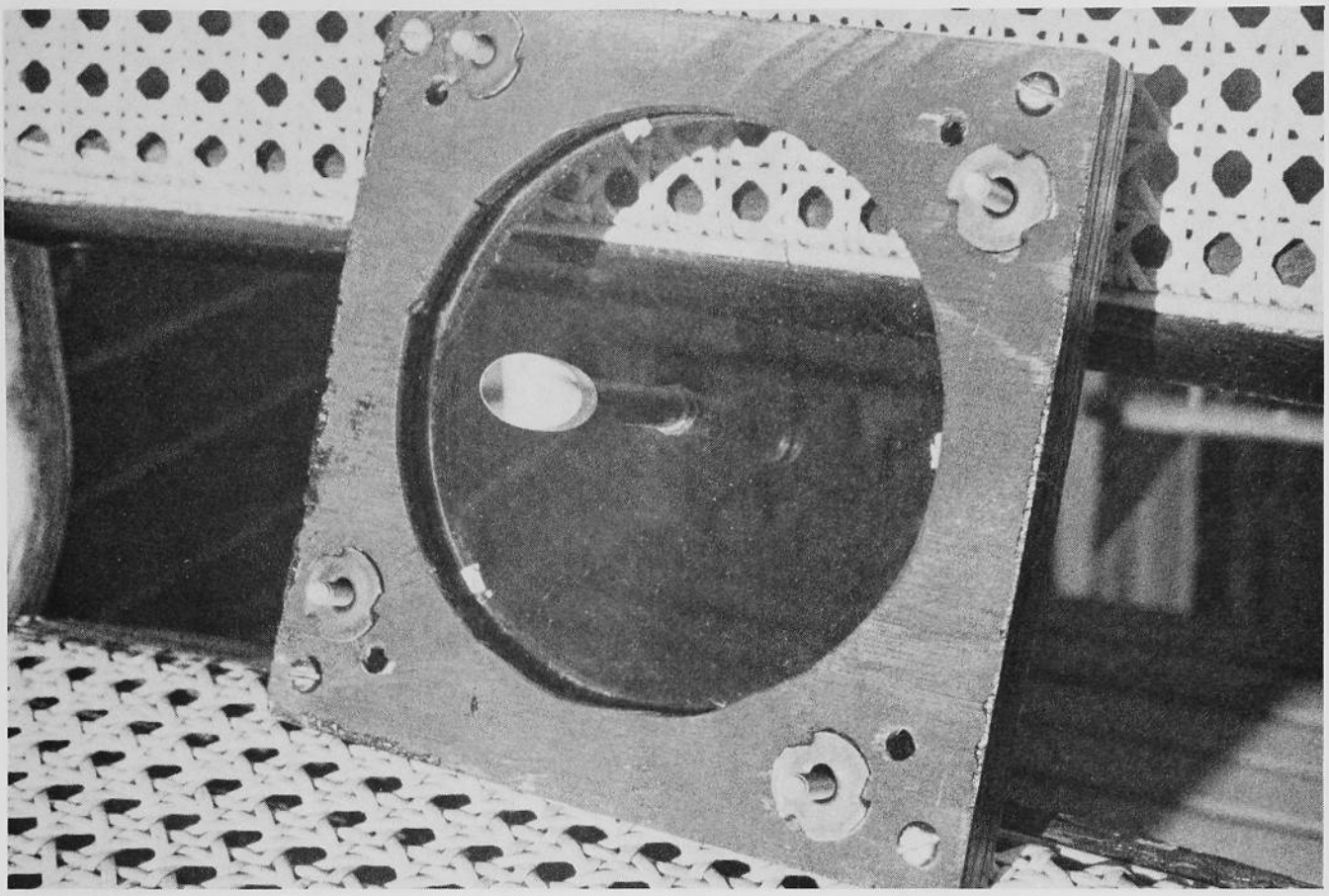
It took some "tuning" to make the telescope work correctly. The first time I took it out, the window dewed up in twenty minutes. A dew cap is necessary. In this design the dew cap also blocks stray light entering the tube through the gap between the tube and the window cell. When I carried the scope around in my car, the window and diagonal would vibrate around in their cell, knocking the scope out of collimation. I wedged little slivers of cork between the window and the outside piece of the cell to cure this.

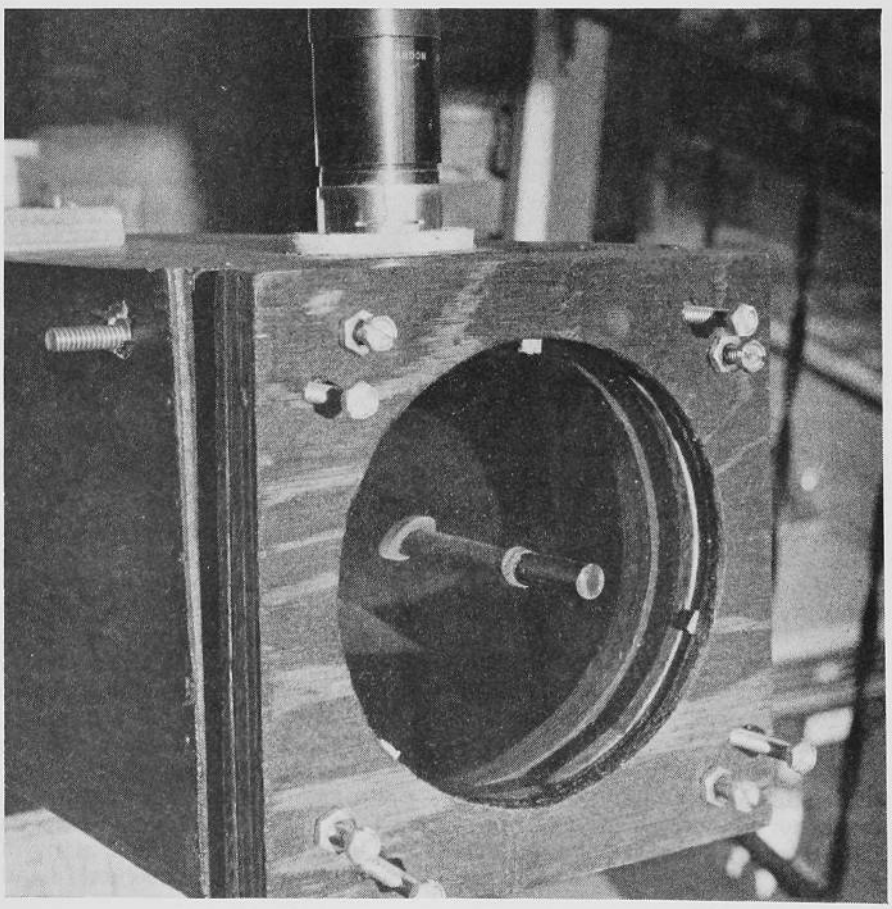
Getting good contrast took some care. Every time I painted something black or blocked sources of internal reflections, the contrast got better, and made those faint Martian details easier to see.

The finder is made from a flea-market lens that I picked up for a quarter, some plastic, and paper tubing.

The Dobsonian mount is very heavy and quite stable. The two sets of bearings allow me rotate the tube to help children reach the eyepiece during public programs. I stained the tube dark brown (sort of a Columbus tradition anyway) so the scope would radiate heat quickly.

The long-focus, smooth spherical mirror surface, lack of diffraction patterns from a spider, no color,





The window and diagonal are the keys to this telescope's fine performance. The diagonal mirror is mounted on a dowel rod attached to the window. Four push-pull screw pairs (two would have been enough) align the diagonal; the window can be rotated by the dowel attached to the front side of the window when three cork pads are removed.

and only 11 percent obstruction add up to great planetary images. Mars was great throughout the summer. I can often see Jupiter's moon as disks and can split 1.4-arcsecond double stars easily. With the focus just inside the tube, the diagonal just covers the entire Moon. At low powers, the field is vignetted at the edges. I don't care about this, because I'm only worried about the center half-degree field of view.

I have since used techniques I learned on this scope to "fine tune" my other scopes, for instance, painting the inside of the focuser. Each little fix makes a difference, and they all add up.

Robert Bunge
110-1/2 Wilber Avenue
Columbus, OH 43215

RTMC 1989

Riverside often begins at the end for me, when I begin to put what I've seen and heard into some kind of order. Getting the facts down is easy, the ordering takes time way from the hustle and distraction, away from dining halls and telescopes and talk of the latest CCD chip.

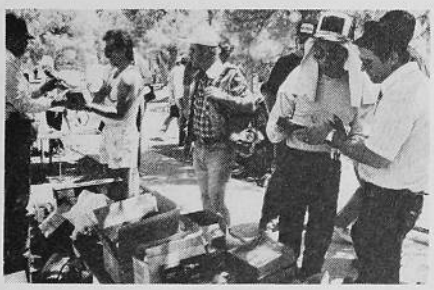
So I went to the wilderness and hiked puffing and panting to Onyx summit carrying nothing but a camera and my portable computer. Where I now sit isn't the summit exactly, but it is somewhere near the top. It's quiet—all I hear is wind in the tree I'm sitting under and the sound of its branches creaking.

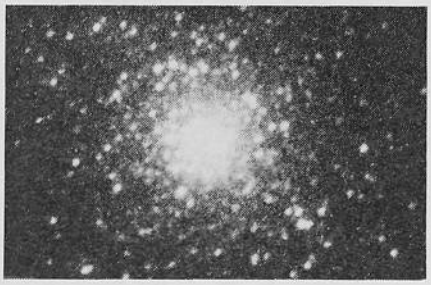
The facts about this year's RTMC are easy: four clear nights, something like 2,800 people on the site Saturday afternoon, a super swapmeet that I saw very little of, and a well-controlled and healthy mix of amateur and commercial instruments on the telescope field. There were this year 45 entries for telescope merit awards, and was on the merit award committee so I saw them all.

Of all the telescopes I saw this year, I was most deeply impressed with Jose Sasian's 6-inch aperture unobstructed Yolo-Herschelian. It was, by far, the most innovative optical design. You can and should be skeptical of this design because the conventional wisdom says it should be hard to make, but Jose has built one and it works.

The idea is this: if you tilt a 6-inch f/12 paraboloid off axis, as William Herschel did with many of his telescopes, the observer's head or an eyepiece do not obstruct the incoming beam of light, but the image suffers from severe coma and astigmatism. Such telescopes are called Herschelians. Newton used the primary mirror on axis, with a small flat to send the image out the side of the tube, thereby introducing an obstruction into the beam, but keeping the optics simple and rotationally symmetric. These are called Newtonians.

Jose tilts the paraboloid about five degrees, and adds a concave secondary inclined about 45 degrees to the beam, reflecting the light across the incoming beam. By deforming the secondary's surface into a toroid, he corrects some 200 waves of astigmatism from the primary to produce a diffraction-limited image with an unobstructed





system. Jose developed the telescope as an extreme example of the Yolo design using the design equations in his article in this issue of *TM*. Jose's description of the Yolo-Newtonian/Herschelian will appear in the next issue of *TM*.

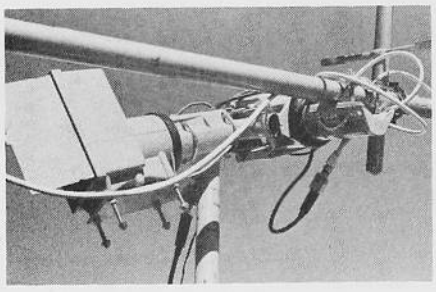
On Saturday night I spent about an hour with him carefully checking out the system's performance. The legs on Jose's wonderfully inventive mount don't slide smoothly on grit-and-rock ground so it was hard to make delicate moves, and the pitch of the screws is too fine for large motion. I fought the mount for about fifteen minutes before I could find and track a bright star.

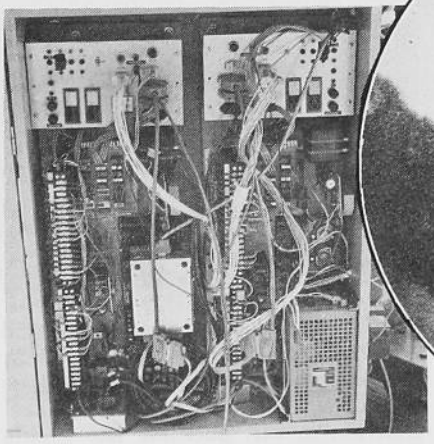
Once I got the hang of it, Jose gave me a 12mm eyepiece and I carefully examined the star's image inside and outside focus. With a small mask to block a slight turned edge on the primary in place, star images are the same on both sides of focus. I never saw clean diffraction rings, but because the seeing was poor I didn't expect to see them either.

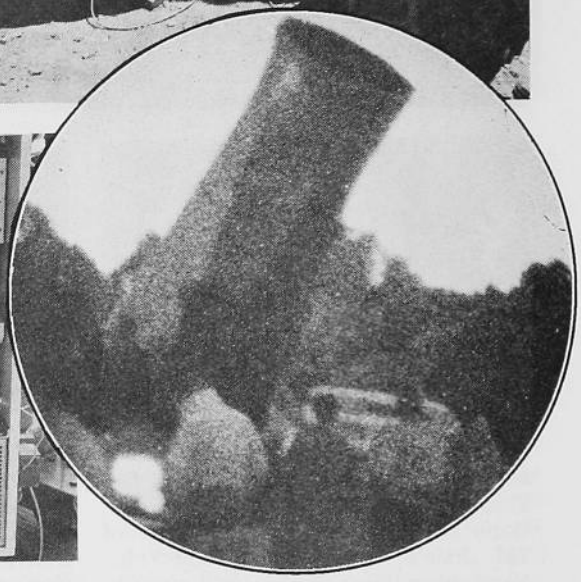
To demonstrate how much aberration the toroidal mirror corrects, Jose loosened the clips that hold the it and invited me to rotate it slightly about the optical axis. I twisted it about 1/16 of an inch clockwise—and the star showed 30 arcseconds of astigmatism. Whoa! Rotating it about 1/8-inch counterclockwise produced equally huge errors with the opposite line-focus orientation.

After three or four tries, I got the images pretty nearly round again. If the seeing had been good and the mounting a solid equatorial, I'm sure I could have gotten it perfect. The tilt of the secondary and the mirror spacing can also be adjusted. Once set up, such a system should be pretty stable.

Because toroidal surfaces are notoriously difficult to make, I questioned Jose closely about making the secondary. In this design, one axis has a radius of 6 meters and the other 12 meters. Jose said it really wasn't particularly tough. He worked the secondary by hand, and began to make the surface toroidal in fine grinding, by using a linear stroke and not rotating the workpiece on the tool. A four-bar linkage will keep the mirror aligned during grinding if necessary, but during polishing, he told me, but once it has started to become toroidal, the







Run by a Commodare 64, SARA's 600MHz receiver was ready for drift scans of the Sun. The LAAS 31-inch and its on-board computer control.

mirror tends to align itself and will not rotate on the polishing tool.

For the amateur optical buff, this system should be fun to make. Making a 6-inch f/12 paraboloid ought to be like fall off a log, and the secondary is small, so grinding and polishing step ought to go quickly. My greatest concern would be putting the super-smooth finish that makes unobstructed systems work so well on that toroidal secondary.

I spent all day Saturday examining telescopes for the Merit Awards—not a problem because I try to see all the telescopes for *Telescope Making* anyway—and a good part of Sunday morning closeted with the awards committee. Anyway, perhaps a few observations on the process might be in order—just remember that I'm speaking as myself and not on the behalf of the committee.

Broadly, what we looked for were telescopes that either gave something to the community of telescope makers or advanced the art of telescope making. Unique designs, novel construction techniques, innovative use of materials, and superior execution of tried-and-true ideas contribute to those ends. In effect, the award is a way of saying, "In building this telescope you have given something to all of us. We learned from examining your telescope and might incorporate ideas from it in our next telescope."

I looked at the telescopes with committee member Rick Shaffer, and enjoyed the chance to see every telescope registered. Rick tended to stop and talk too long with projects that had electronics in them, and I tended to get involved in those with interesting optics and mechanics.

Bob Drew, Bill Wells, Paul Campbell, and Randy Pakan built this "astronomer-proof" Dobsonian portable for the Edmonton Centre of the RASC.

That made us a virtually perfect team—we took too long at every telescope.

By the time darkness fell, I was quite tired, but I borrowed the Saguaro Astronomical Society Litton M-911 image intensifier (courtesy of Gene Lucas) to try shooting pictures of telescopes and through telescopes. This year with shooting directly into the eyepiece of various telescopes. I succeeded in capturing Pluto in a quarter-second exposure through Paul Mahany's 18-incher, the Dumbbell in Gary Grue and Tom Scott's 24-incher, M7 in an 8-inch that belonged to some friendly folks, and lots of pictures of people waiting in line or looking through various telescopes. All in all, I shot two rolls of film with the scintillating greenish glow of the tube to make the grainy, round pictures you see with this story.

Sunday night was as clear and dark as the previous two. I joined the group watching the output of Tom Quinn's CCD television system. This is Tom's third astronomical TV system; as a member of the Orange County Astronomers, he will soon be testing it on the 22-incher at the OCA's Anza Observatory (see *TM#31*). After successes on the two previous nights, Tom had decided to team up with Canadians Doug George and Robert Morris and their Telescope Graphic Display System. This is a PC-based mouse-operated telescope controller that projects the image from a miniature monitor into the eyepiece of a box attached to a C-8 on a Super Polaris mounting.

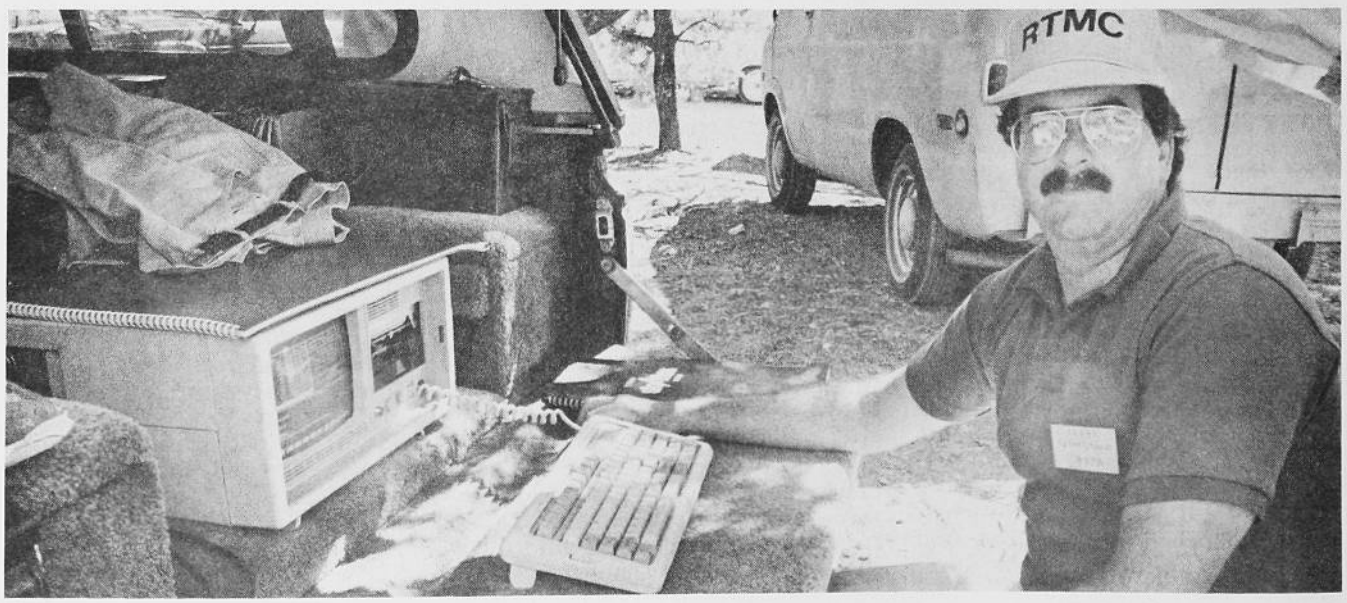
By flipping a switch, Tom and Doug could view either the CCD camera output or the output from the video finding system. It took a while to get everything working right, and a further while to find the first object, M51. Because the finder telescope wasn't or wouldn't stay in alignment, they were stuck finding everything in the quarter-degree field of the CCD. Between each move, we waited through a ten-second exposure and a three-second readout. Finally, by offset-

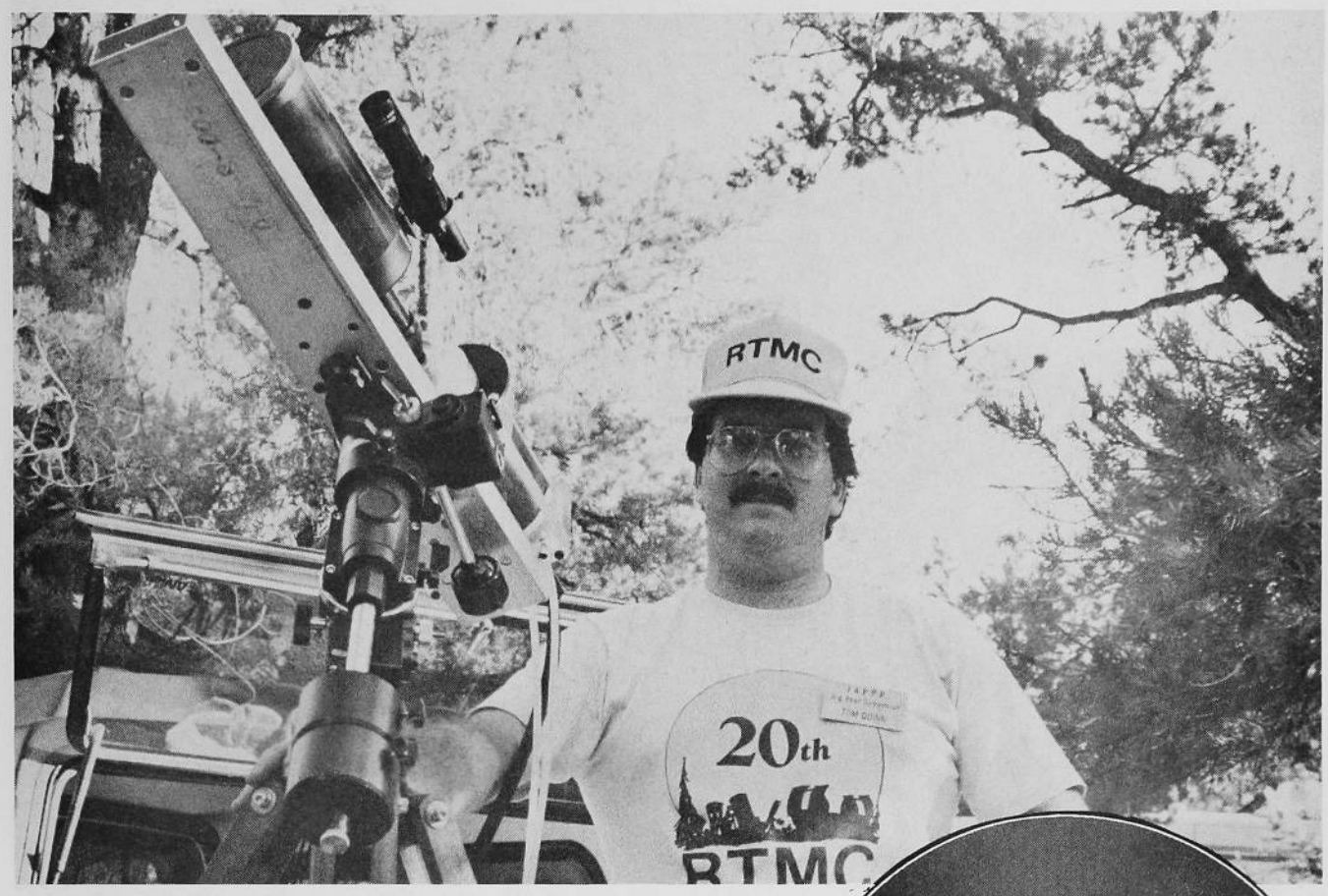
Continued on page 42...

CCDs Show Their Stuff Chip Gives Striking Performance at –55°C

"Big advances are coming in CCD technology," says Tom Quinn of the Orange County Astronomers. Tom has developed a CCD camera using the Sony LPQ235 chip and plans to test the camera on the OCA telescope. At Riverside he demonstrated the camera on a 4-inch Meade spotting telescope—with impressive results.

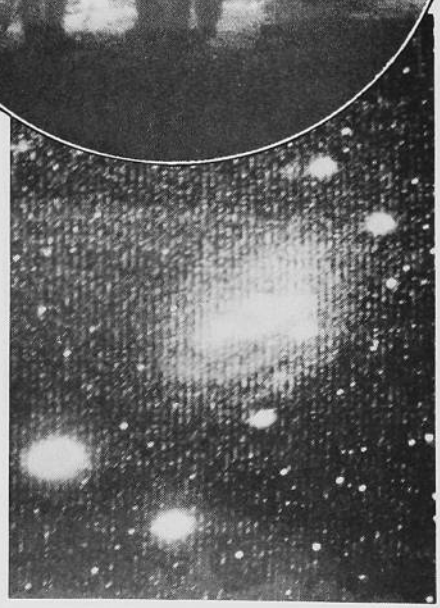
The chip is mounted in a vacuum chamber and cooled by a thermoelectric cooler. Tom uses a water bath to remove heat from the "hot" end of the cooler. Even at –40 C, Tom says he doesn't see the dark cur-

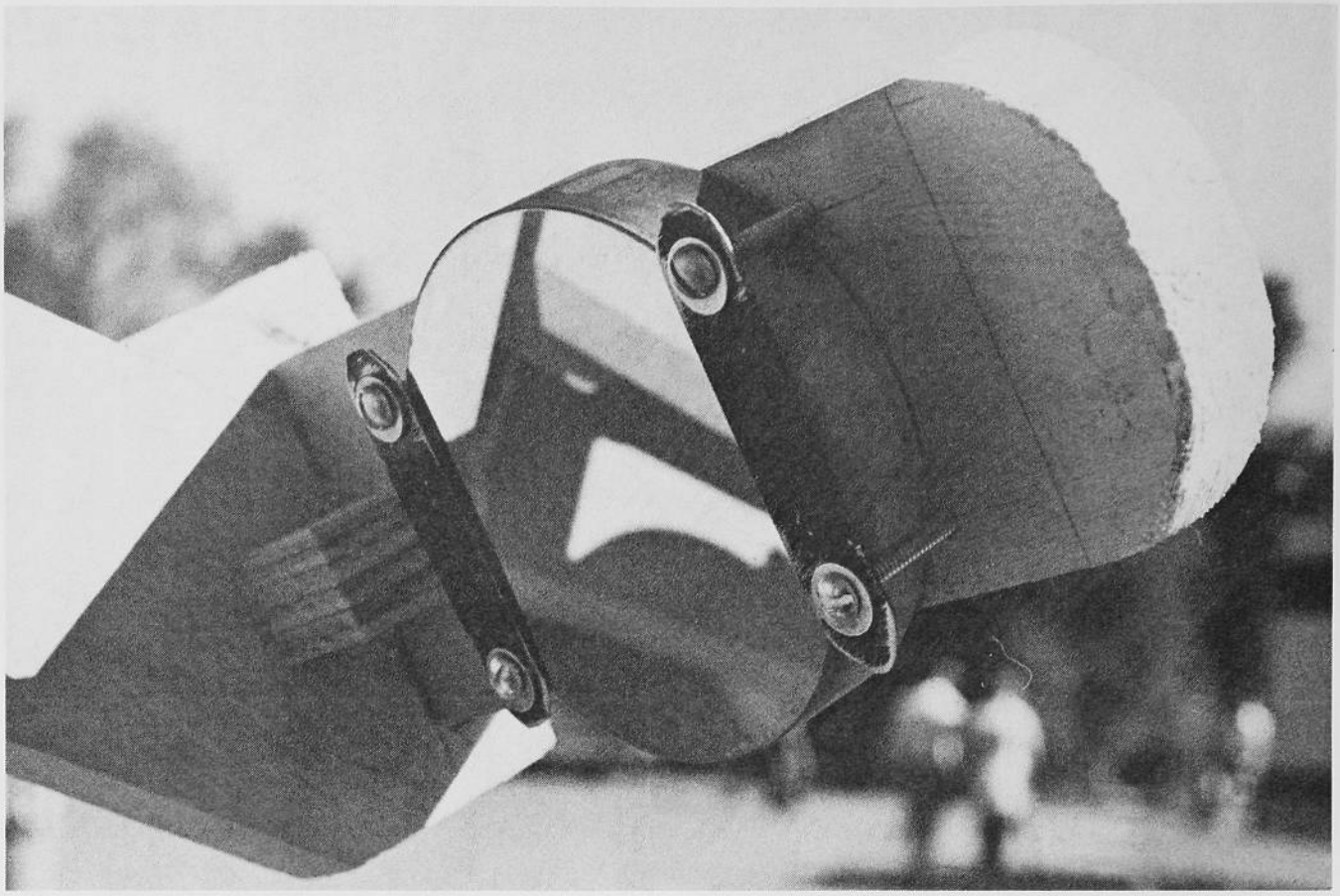




rent in 2-minute integrations. "It should reach 20 electrons per pixel readout noise at the optimal temperature," he claims. Data is scanned out at 45 kHz.

Tom expects better pictures with a larger telescope and a cooler CCD. Running at -50C, the chip had roughly four times the dark noise that it would at -65C, the nominal operating temperature of the system. On a telescope with five times the aperture for a larger image scale and four times as long to collect photons, this CCD camera system should be awesome.

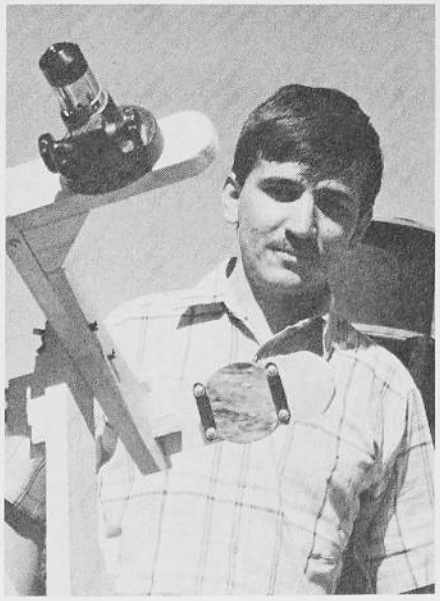


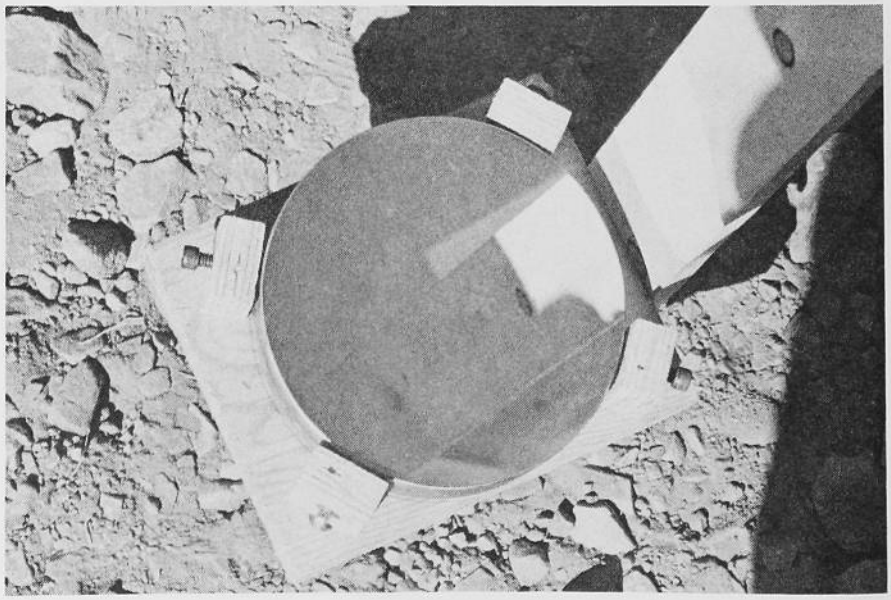


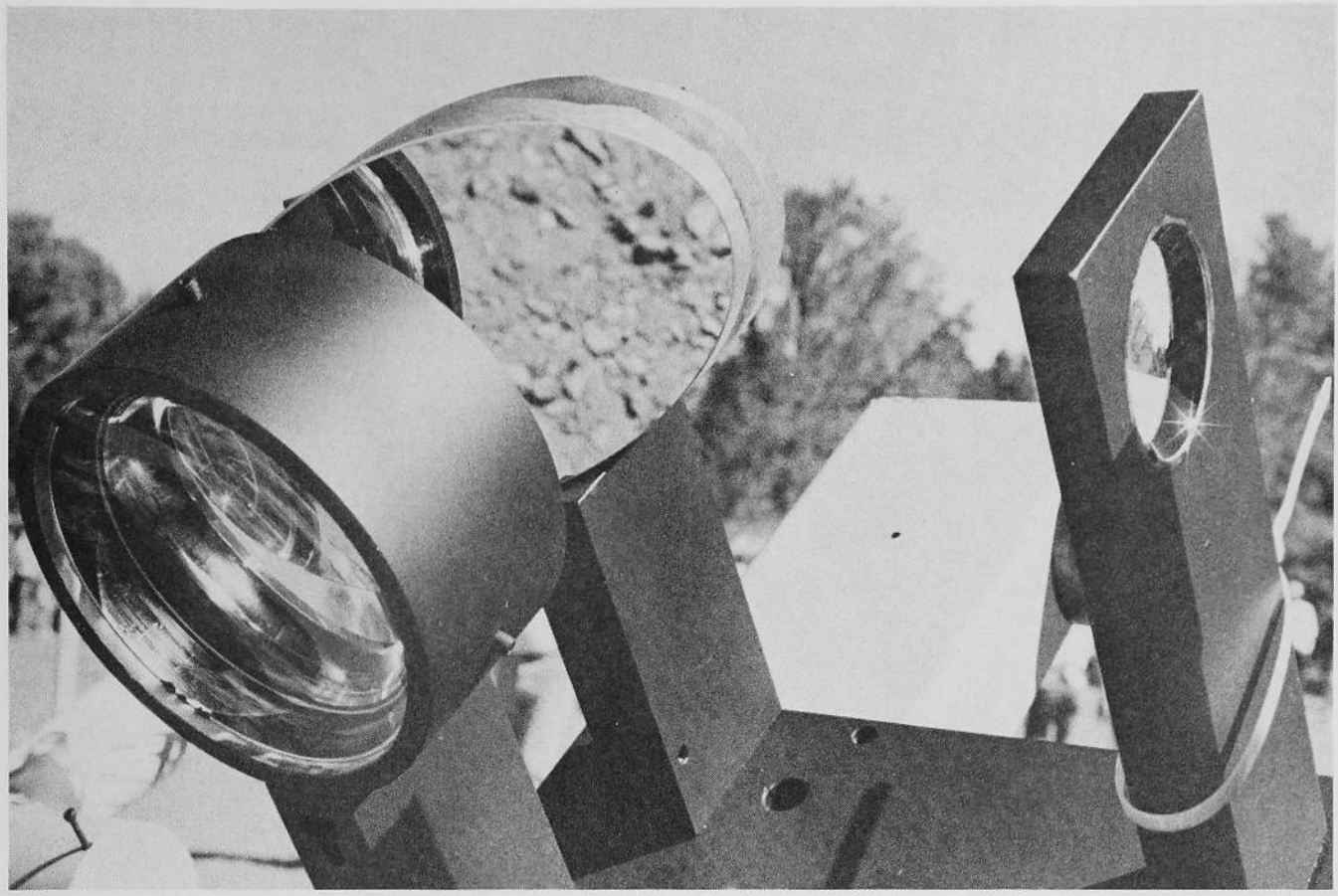
Yolo Design Pushed to the Max Toroidal Secondary Works

"This is about the limit," says Jose Sasian, of his f/11 Yolo-Herschelian/Newtonian telescope. Sasian, a post-doc at the Optical Sciences Center in Tucson did a methematical analysis of the Yolo and developed design equations for these two-element systems.

The telescope he showed at RTMC has a 6-inch f/12 primary mirror and a concave toroidal secondary tilted at a 45° angle, a hybrid of the Yolo with Herschelian and Newtonian telescopes. The secondary is not difficult to make, says Sasian, who made the optics.



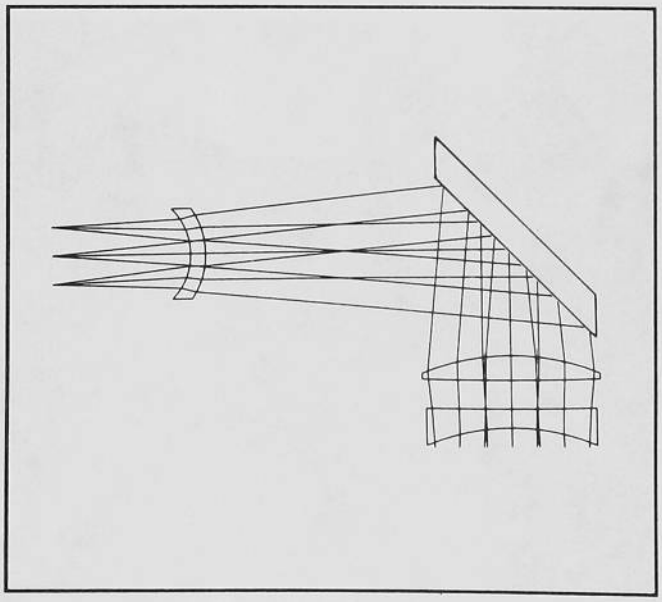


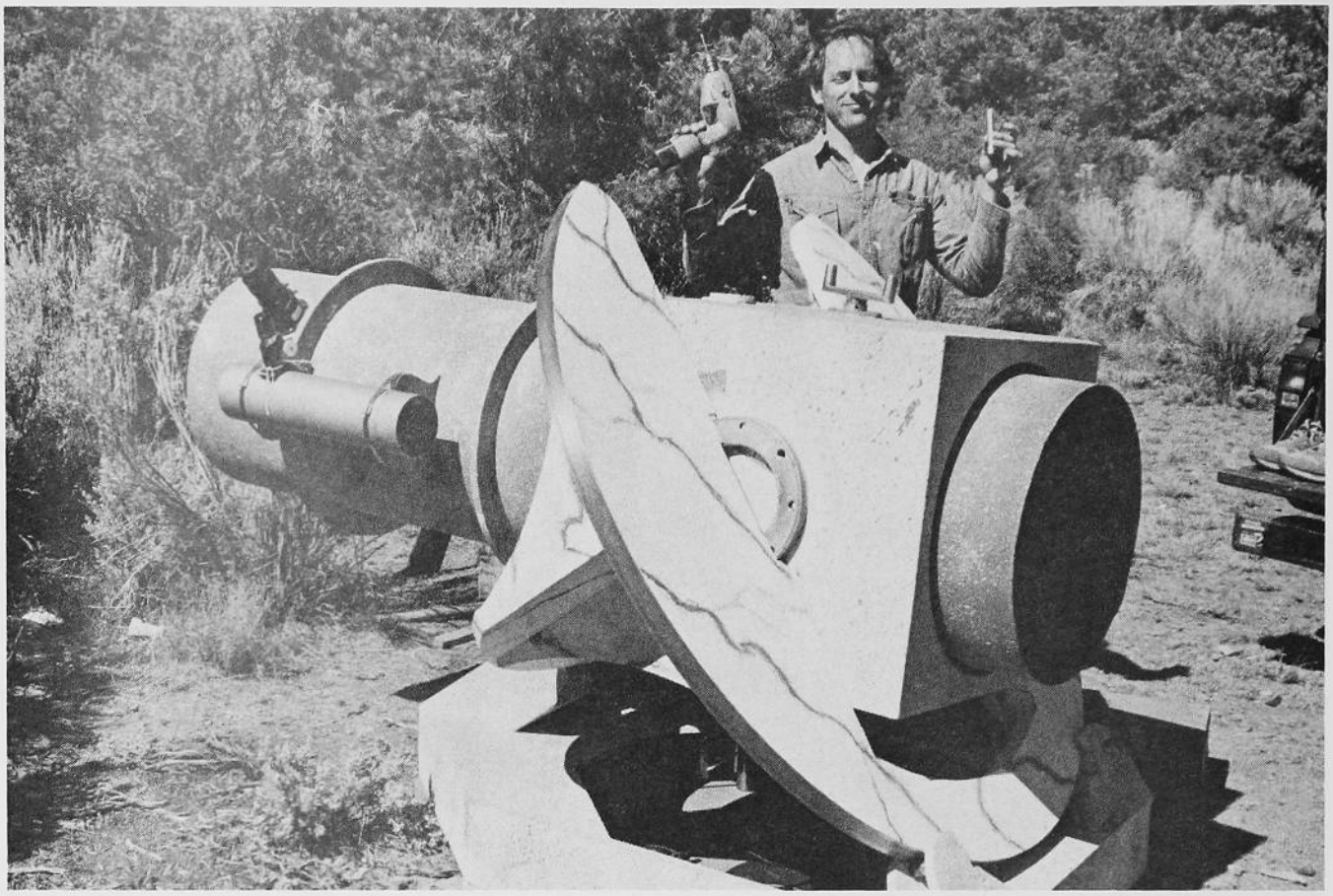


Prototype Proves Schalck-Newtonian Is Not a "Paper Telescope"

"Maybe something like a quarter of the really serious amateurs could make this system," says Bob Schalck, designer of this well-corrected all-spherical telescope originally described in *TM#31*. The design provides a wide, flat field for astrophotography.

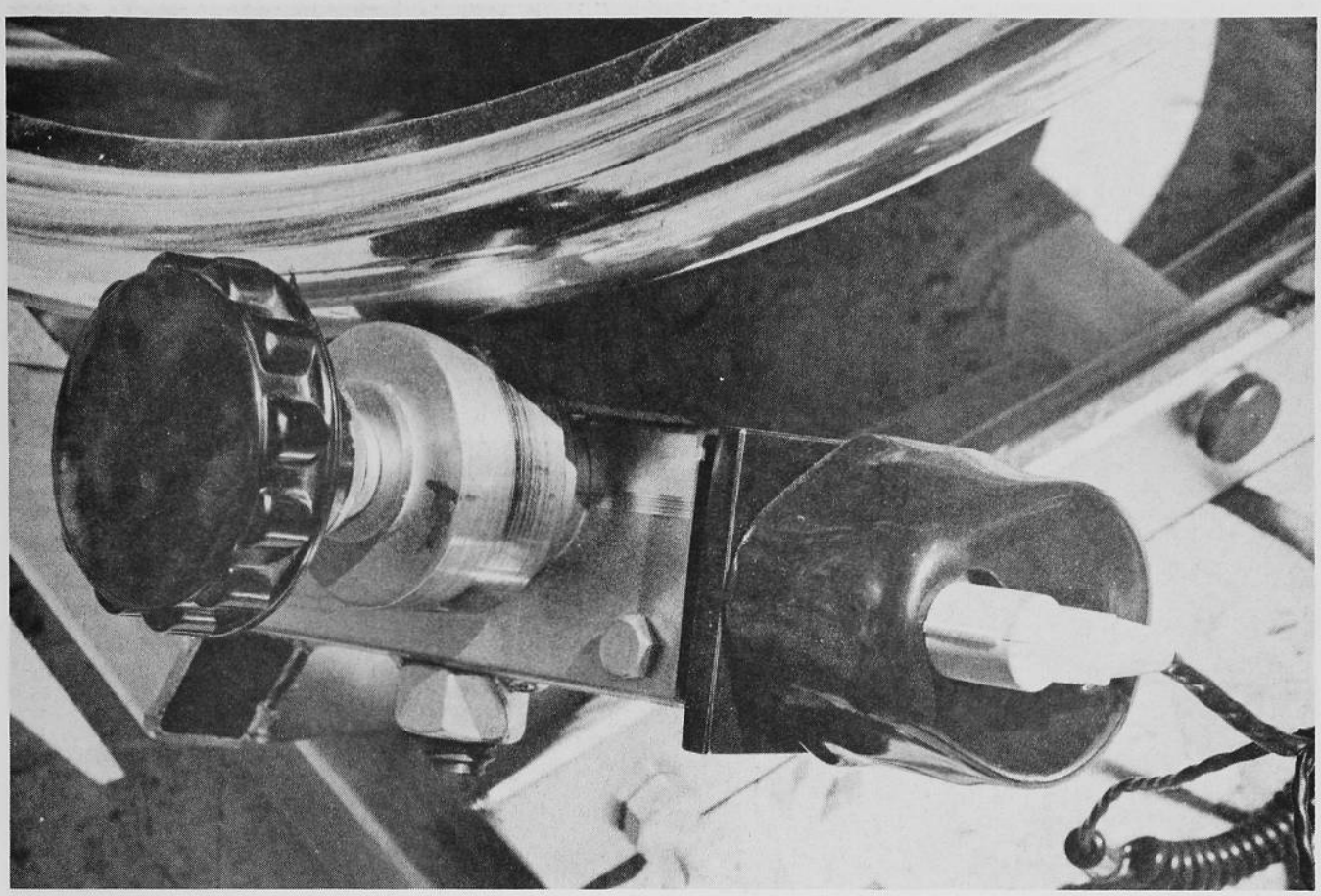
Schalck showed the working 12.5-inch f/5 prototype on an optical bench mounted on an equatorial. He had the optical shop that made the prototype prepare five sets of the lens blanks. These are available to amateurs who would like to build the system.





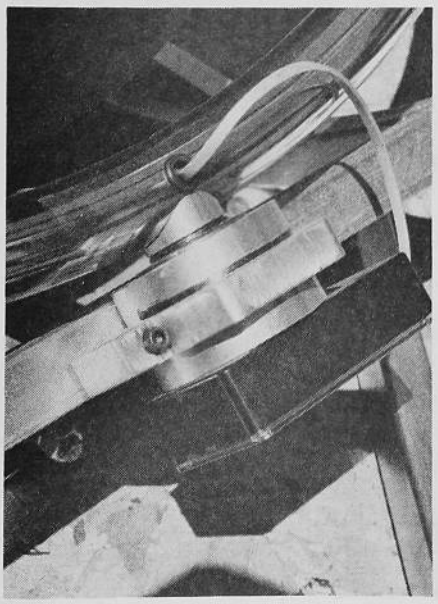
Split-Ring Equatorial Gathers Momentum Massive Mounts Are Solid

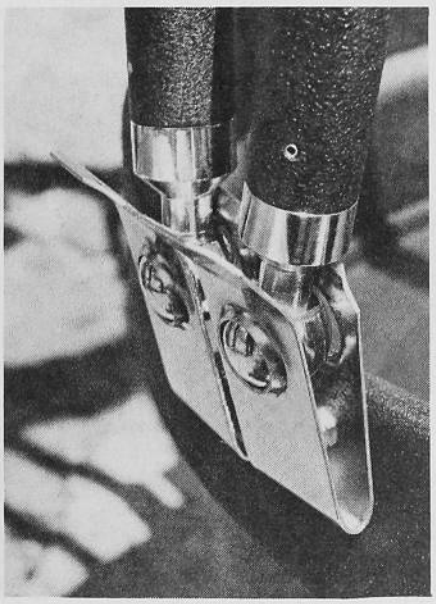
Paul Mahany's massive 18-inch f/4.6 and Ronald Mallory's 6-inch f/5.8 telescopes testify to growing interest in the split-ring equatorial mount. Mahany's 60-inch polar disk was cut on a jig on a table saw to an accuracy better than Mahany could measure. Inside the large tube box are conveyor-belt rollers on which the heavy tube turns. The drive roller is a selected extra-hard skateboard wheel. Mallory's 30-inch diameter disk is made of 3/4" plywood and turns on rubber rollers, but is driven by a worm gear at the south end.

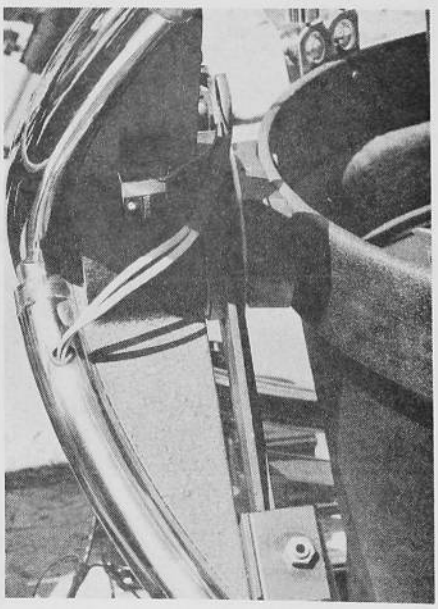


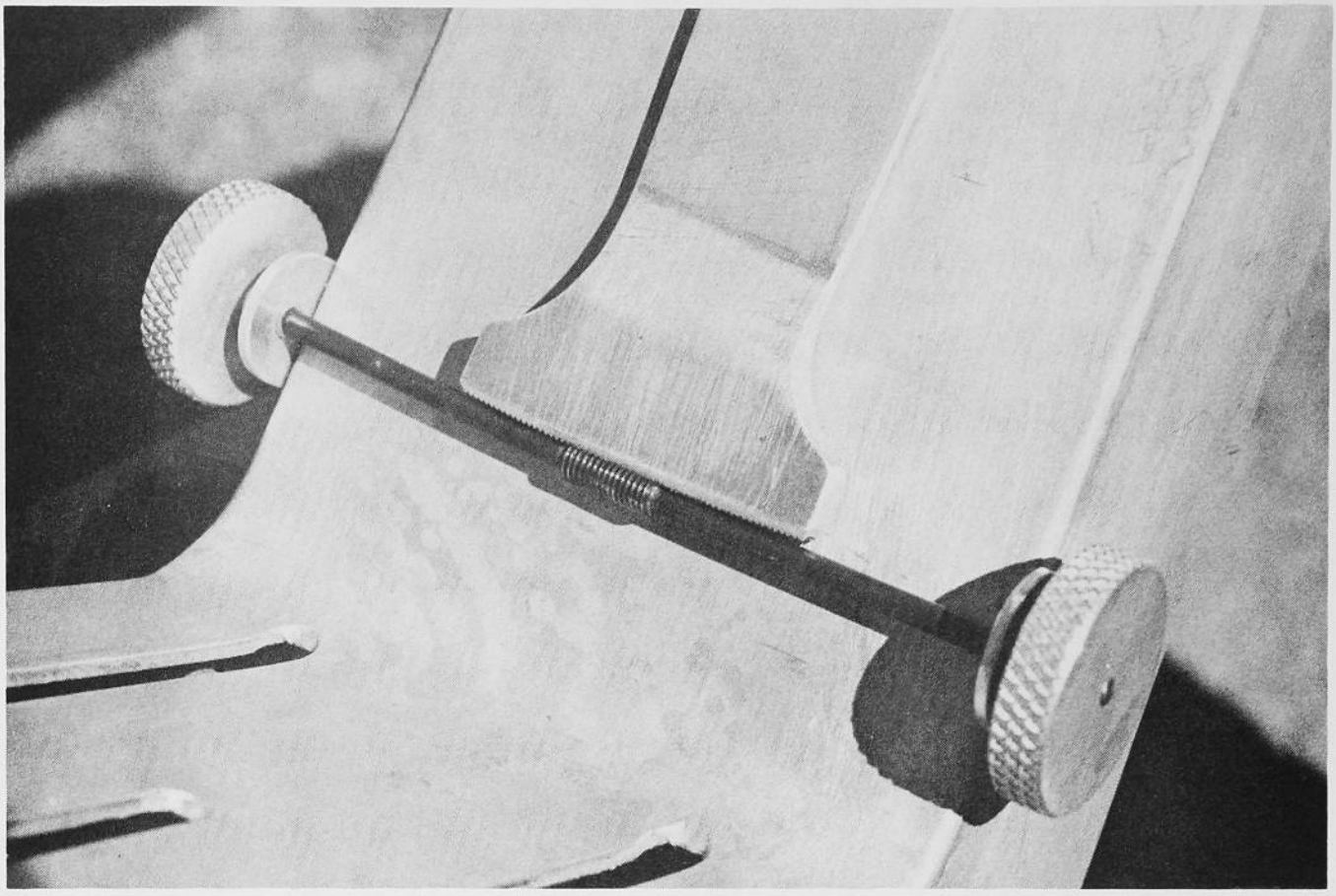
Made for commercial sale by Jim's Mobile, the NGT-18 has features telescope builders will find interesting. This split-ring mount is fabricated from 1.5-inch steel tubing rolled, welded, and chrome-plated; it's simple, clean, and elegant design work from start to finish. The drive roller is stainless steel and, as far as I could tell, just about can't slip on the very small contact area. The digital readout for RA position is located on the south end of the polar axis; in declination, it's located on the non-driven end of the declination axis.

Hints for Amateurs In a Telescope Designed for Production





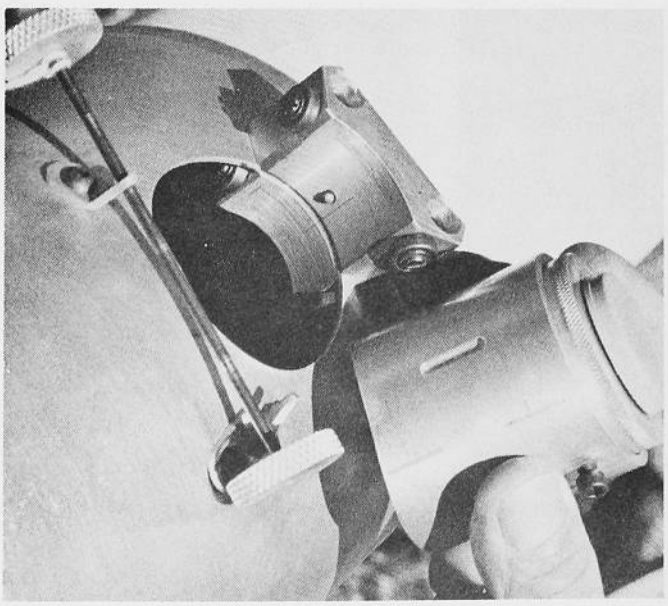


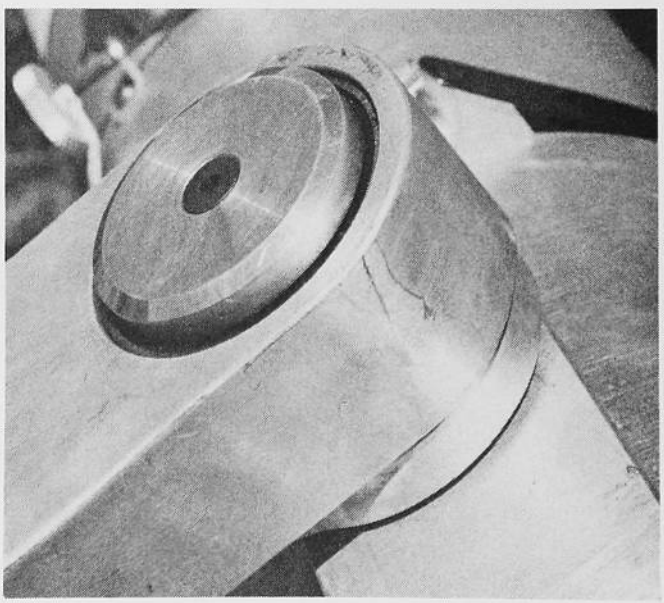


Clever Design and its Clean Execution in Aluminum

Peter Hirtle's 5.4-inch f/4.5 Maksutov stood out in both design and fabrication. The coma-free flat-field optical system designed by Herman Dittmar gives a crisp image at low power and good definition at high power. "Optical collimation was machined in," says Hirtle. He rolled and welded the tube from flat stock.

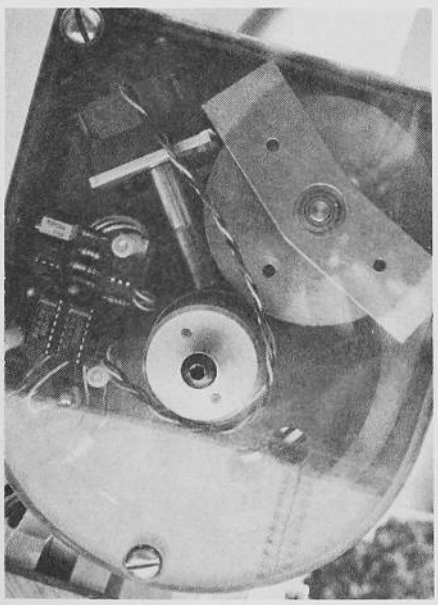
The Crayford-type focuser relies on a pin to prevent rotation, and is kept under tension by bending the welding-rod alloy shaft of the focus knob. The declination axis bearing is a VW Rabbit two-race angular con-

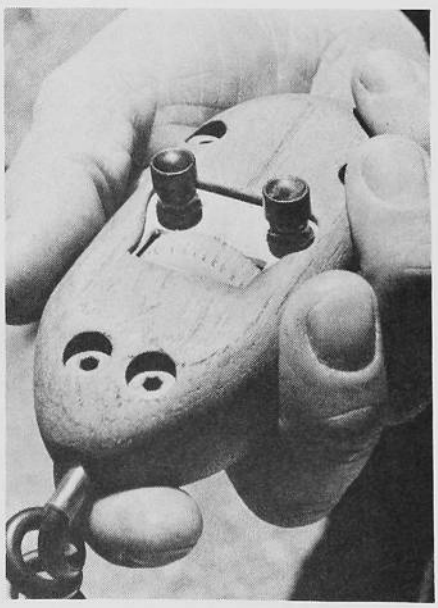




tact bearing. A bent-rod worm drives a gear segment.

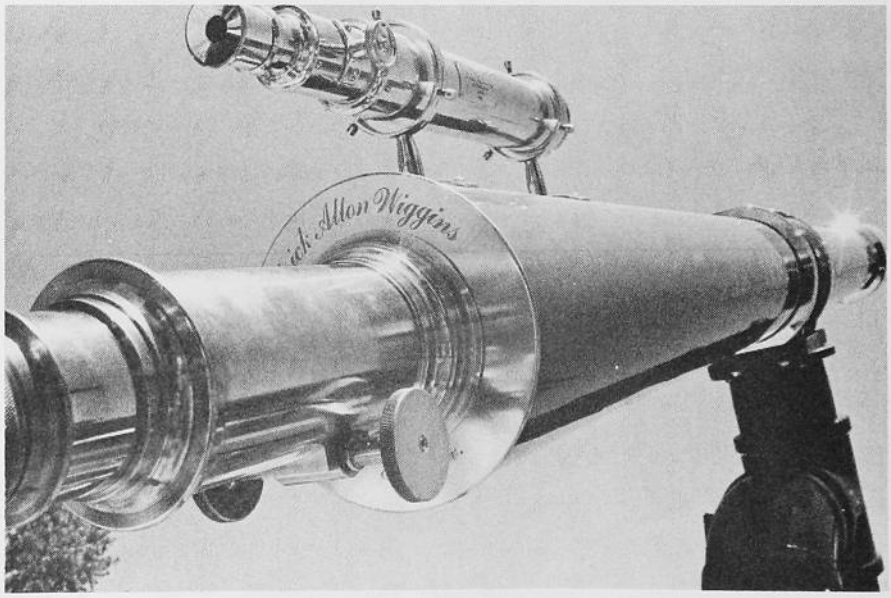
Slots in the fork provide access to screws for shifting the fork to balance the telescope and accessories. Fabricated from 0.078" aluminum, the fork is internally reinforced. Hirtle feels this fork is not as stiff as he would like it to be. The polar axis shaft passes through a 1.5" ball-bearing assembly and carries a steel disk that serves as a drive roller. This is driven in turn by a shaft and 48-pitch 360-tooth worm gear turned by a stepper drive. The hand paddle is made from wood.

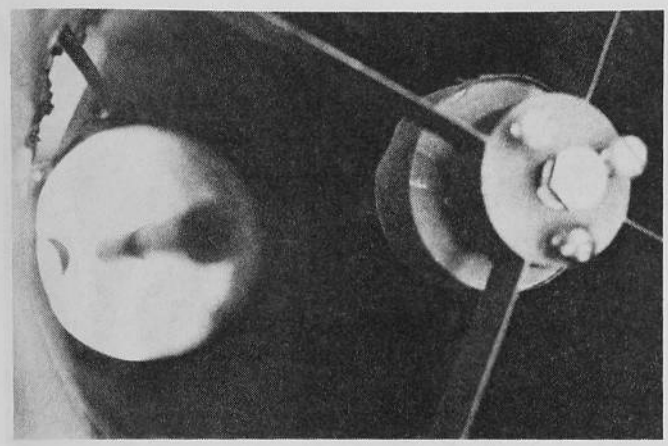


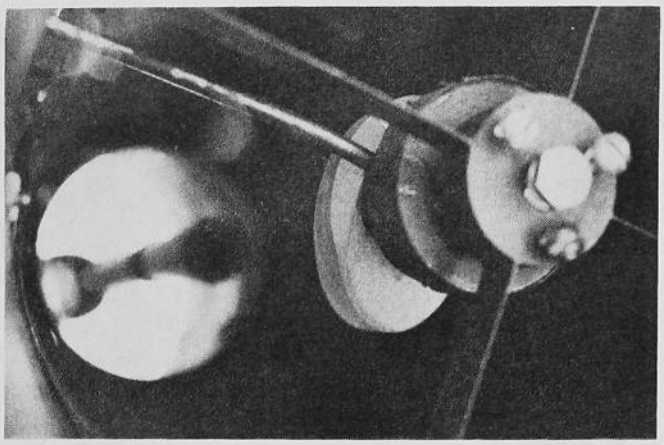


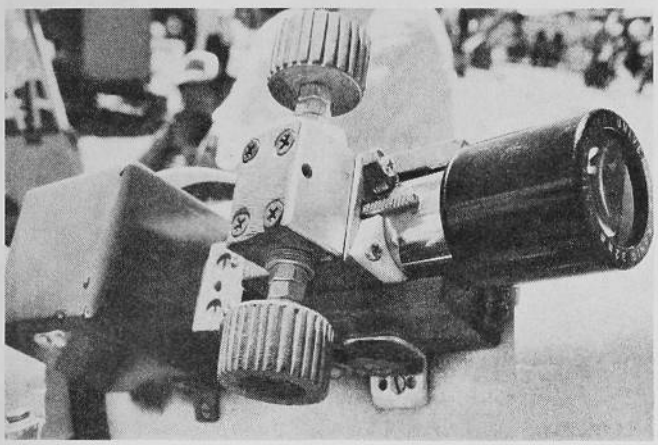
Craftsmanshipin Wood, Metal, and Epoxy Resin for Good-Looking Telescopes

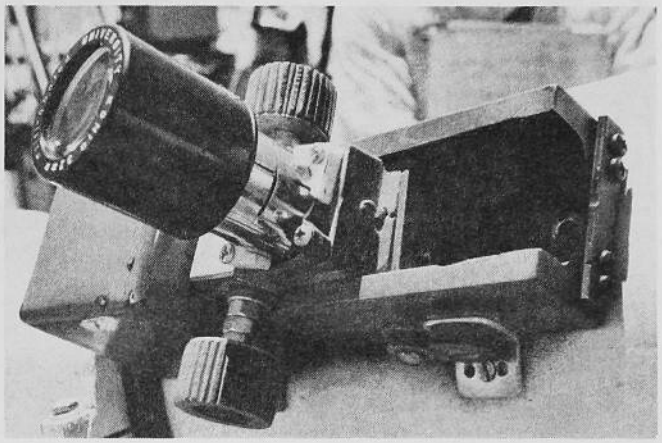
Don Adkins figured out how to make a round tube from Honduran mahogany for his 8-inch f/5.5 Newtonian. Before gluing the sections, he "milled" the inner radius with a table saw. The outside was done with a planner and hand tools. Vince Mele's 10-inch f/6 is his first telescope; it rides on bearings of plumbing pipe, brass shim stock, and wood. Patrick Wiggins mounted a 200mm f/17 refractor on a mount made of cast-iron sewer pipe and oak. The tube is plastic-coated irrigation pipe; the tailpiece and cell are finished in brass.







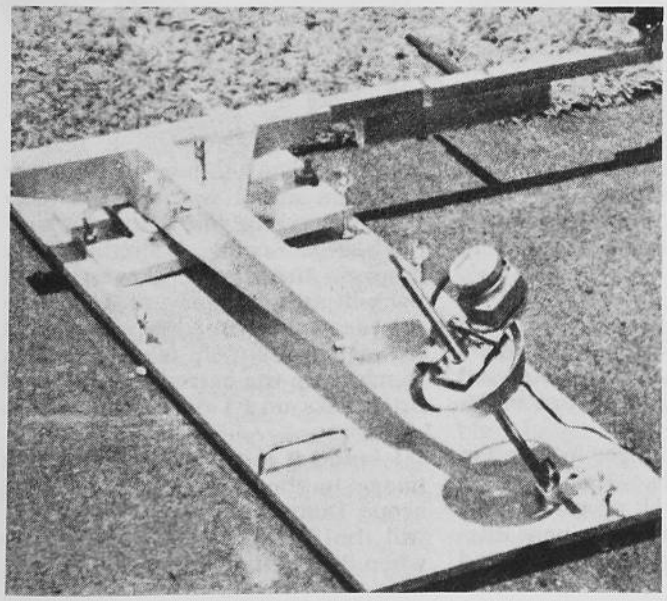


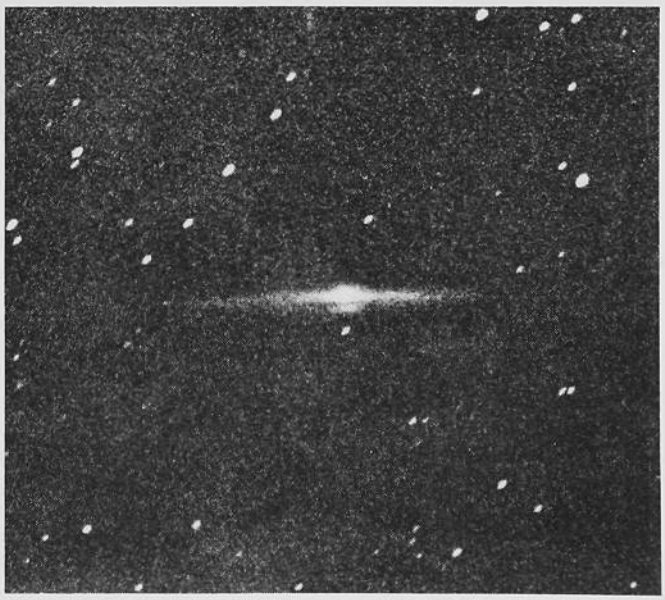


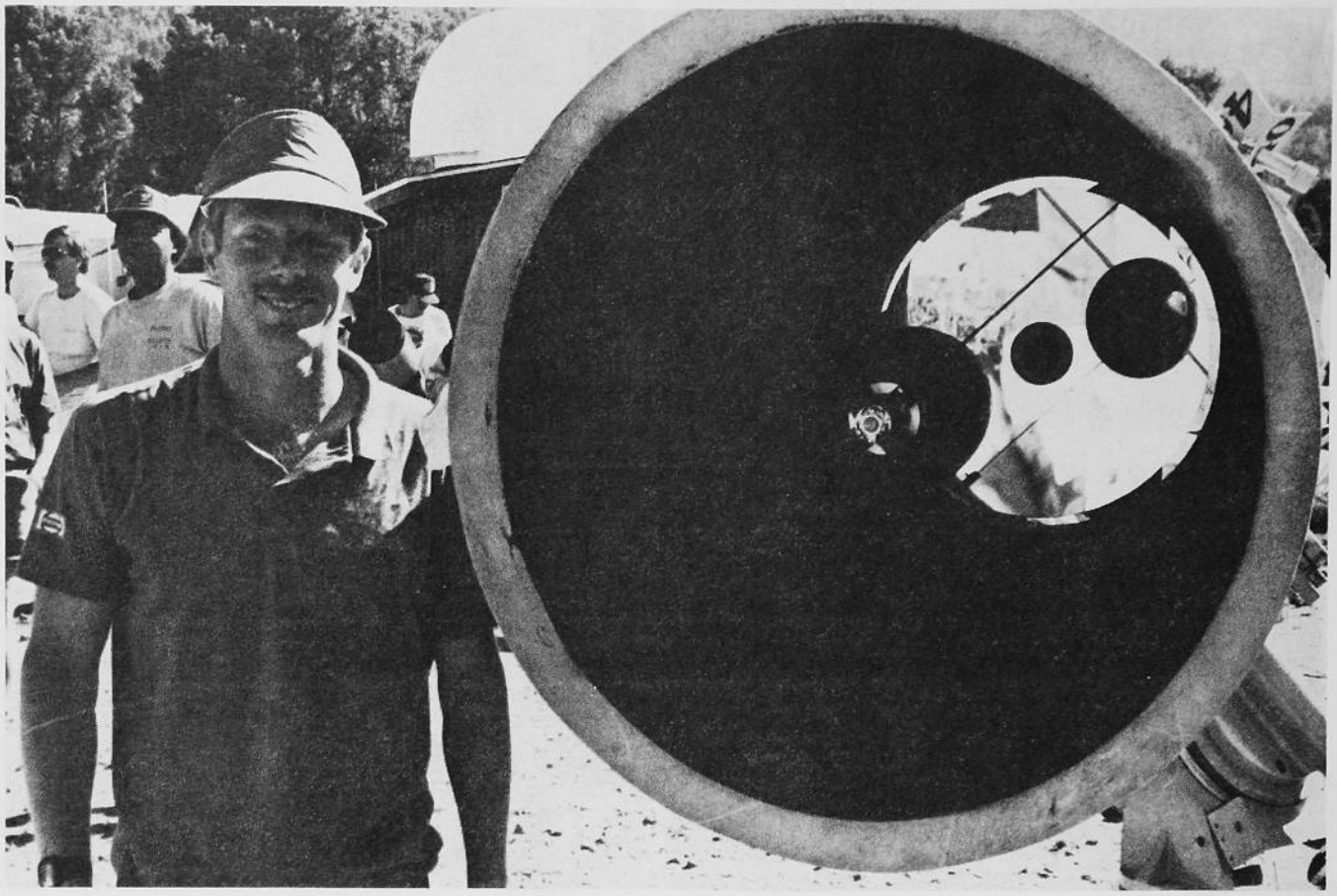
Jim Stevens demonstrated a great way to switch quickly between Cassegrain and Newtonian optical systems with a stalk-mounted diagonal that flips down just ahead of the Cassegrain secondary. Stevens points out that the Cassegrain is the more difficult to align and therefore requires the more stable spider mount.

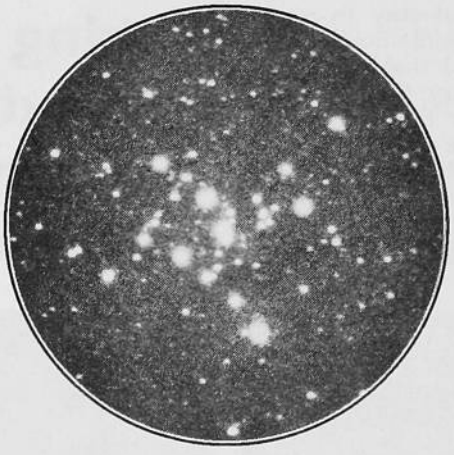
Stevens also showed a rather wobbly prototype of a tangent-arm RA drive for his 17.5-inch Dobsonian. The pivot and arm sit under the telescope. The photo of NGC4565 shows five minutes of unguided tracking.

Putting a Flip-out Secondary in a Newtonian-Cass Telescope









Fiberglass over foam forms the tube of Gary Grue and Tom Scott's 24-inch Newtonian. Debbie Byrd (left) was the featured Saturday speaker.

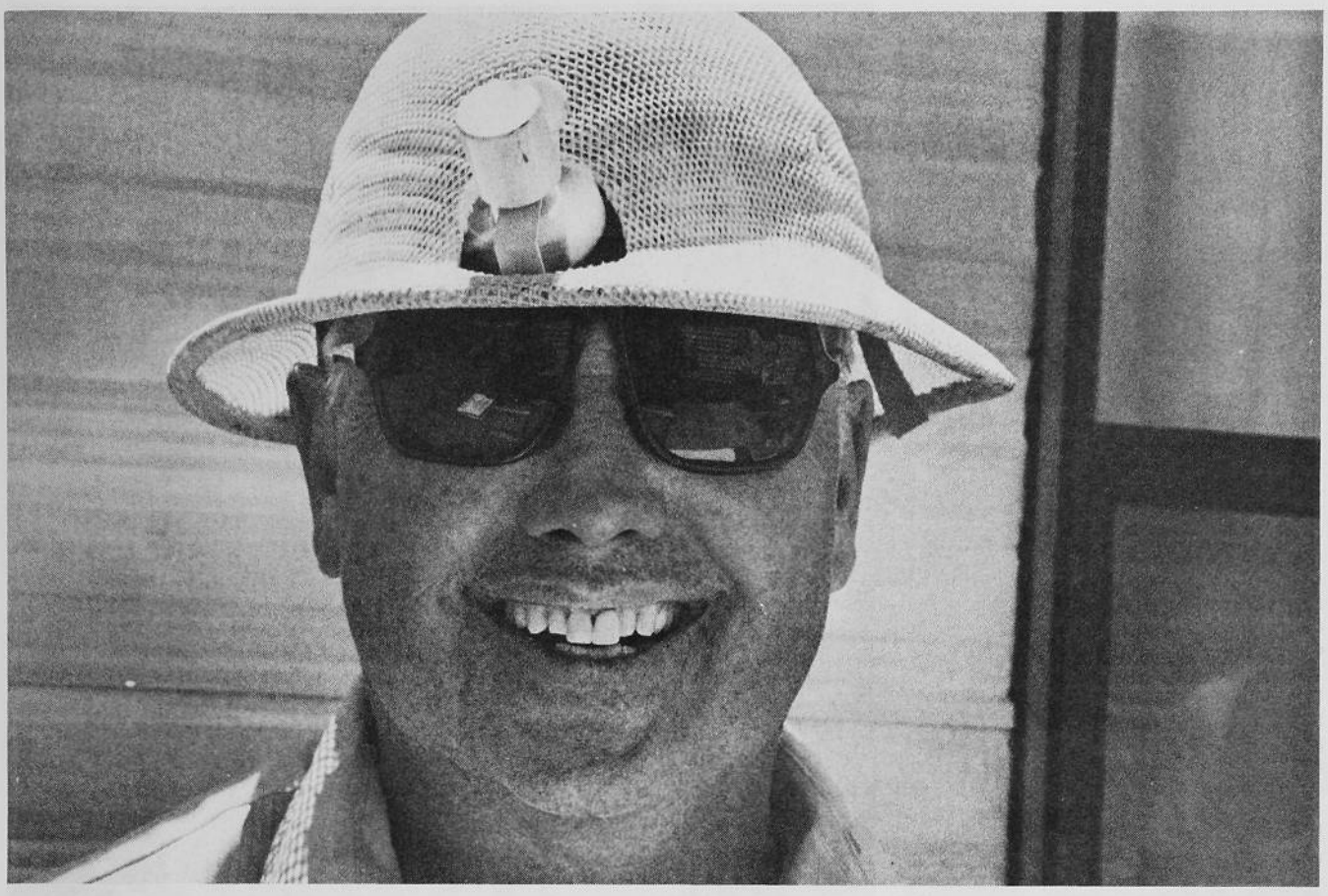
ting from the star at the end of the Dipper's handle, the two nuclei appeared low and outside, on one corner of the screen.

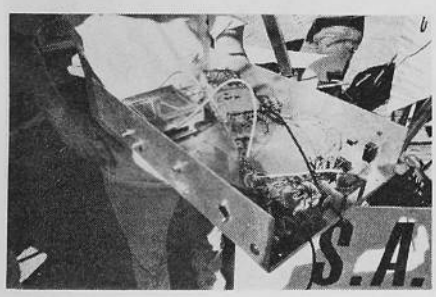
Tom switched the monitor to display the video output of the Canadian system. Doug offset the mouse's position, and Tom then switched back to the CCD. The next scan showed M-51 was now centered in the field, but low. We went back to the Canadian system, another click of the mouse, and another 10-second exposure of M-51, centered.

Tom keyed in a longer integration time—180 seconds. Because of a bug in the control program software, the first scan at a new integration time was garbage. We stood in the cold. As the second integration ran, and I watched the "seconds remaining" line count down.

N5194/95 came up bright, clean, crisp on the screen, glowing like a back-lit transparency of a twenty-minute exposure on fast film through a 12-inch telescope. Tom touched up the screen contrast and brightness and I photographed the screen.

I found it hard to credit the fine image to the 4-inch f/10 spotting scope that had produced it. What will the 22-inch OCA telescope do when it's got this chip at the focus?





Cliff Holmes tries solar headgear to beat the heat. Johannes Vogler and Wolf Peter Hartmann declared RTMC is unlike anything in Germany.

In the hours that followed, Tom and Doug gradually tweaked up the system, lining up the computer-screen display and the real sky. Once the control system was aligned, it was easy to acquire one image after another. Doug picked up M108, the Owl, and a couple of Ursa-Majorian NGCs, each with a click of the mouse, a ten-second integration or two to bring the object into the center of the field, followed by a long integration. Tom stored images of objects he hadn't done before on the computer's hard drive—at 250K per image.

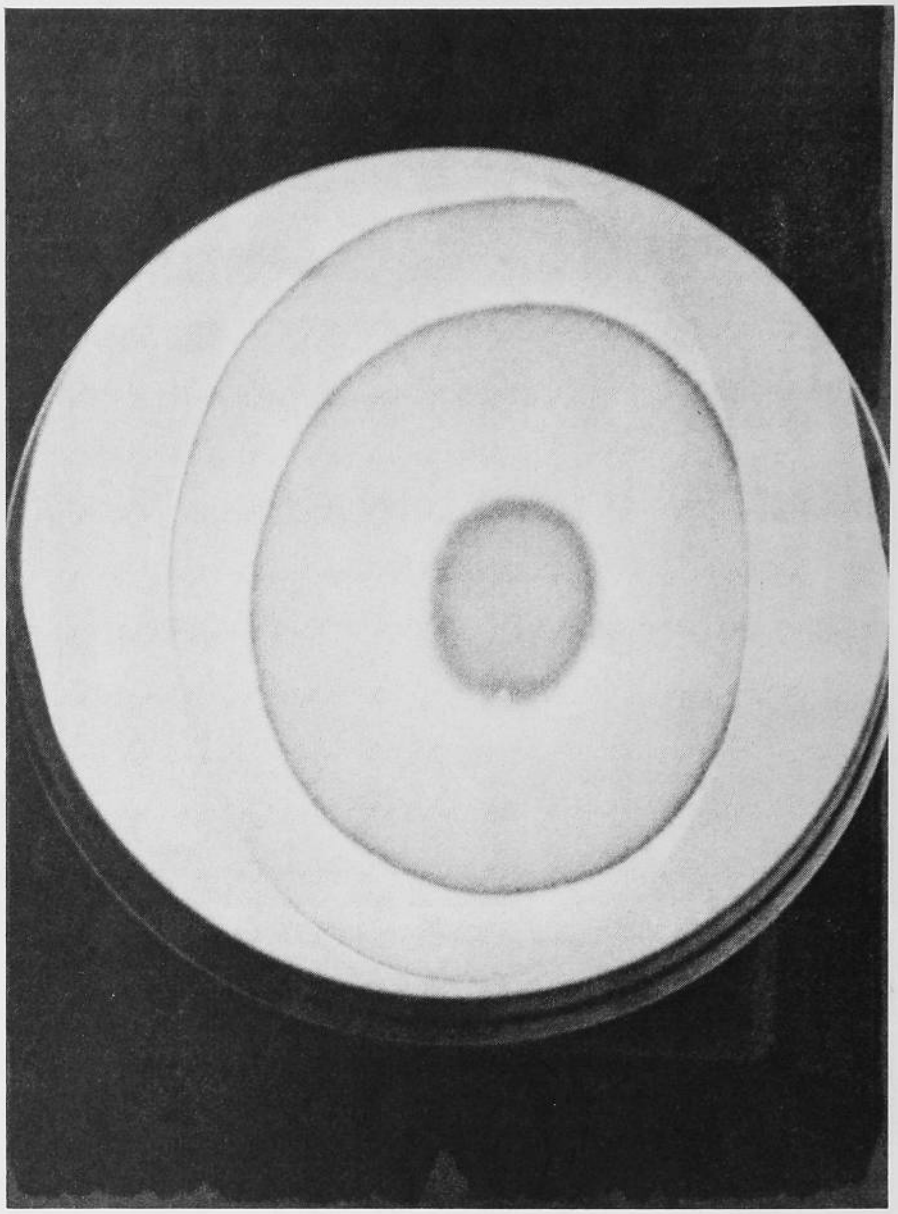
Quinn is thinking of marketing the CCD camera as a commercial product. He expects that a complete system might sell for $15k to $20k. Morris and George are also trying to get a reading on the commercial prospects for their product in the C-8 aftermarket.

It's difficult to guess how new products like CCD cameras will change amateur astronomy. For the time being, they're too expensive to have much impact—but in the electronics field, we've come to expect that prices will fall and quality will rise. When CCDs become reasonably cheap, "serious" projects like searching for supernovae will become eminently do-able for groups like the Orange County Astronomers.

RTMC1989 was one of the best. It was good fun, informative, well-organized, and had something for everyone. It attracted a large crowd of day-trippers, and brought in lots of first-timers. Commercial concerns showed up in force and offered great bargains. Riverside is today less a telescope maker's conference than it was in the past, and more like shows in the hobby industry. But the old hands came out, too, and lent their expertise. In short, Riverside attracts a broad and balanced mix of people interested in astronomy. As it should.

—Richard Berry

Letters



Learn More to Enjoy More

Dear Richard/ The problem of commercial telescope mirrors not living up to their advertised claims is hardly new. In fact, it goes back to the 1950s when commercial reflectors started becoming popular. The majority of mirrors failed to meet advertised claims. There are no Withs, Calvers, Ellisons anymore. I would venture to say that Herschel, who did not have access to the Foucault test, turned out better mirrors than most of today's junk.

Today, amateurs too often accept mediocrity as the norm, just as Americans in general have come to accept mediocre performance in many facets of their daily life. One might call it almost a national malaise. A recent example of this was brought out in the case of a firm that sold pumps to both American and Japanese users. When the pumps leaked oil, the Americans merely wiped it up and didn't complain; the Japanese users complained and the result was a better pump that didn't leak.

Consider the current craze for short f/4 to f/5 optics. Unless you're an expert, you can't hope to make a good f/4 or f/5 mirror, and the problems are compounded if you make it on a thin blank. By the simple expedient of going from f/5 to f/7, you cut your coma and astigmatism in half. Collimation tolerances are not as strict, you can use a smaller diagonal for full illumination, and you're likely to produce a better mirror with less work.

There is really no excuse for amateurs not being aware of f/numbers, optical tolerances, and their bearing on observing. Today's amateur has an enormous amount of information readily available to him -- all he has to do is read it. Us older amateurs had to find out these things via trial and error or searching original sources.

Opticswise, you can become pretty knowledgeable with only three books in your library, namely: 1) Sidgewick's percent ***Amateur Astronomer's Handbook***, 2) Texerau's ***How to Make a Telescope***, and 3) Venrooij and Rutten's ***Telescope Optics***. Add to this ***Observational Astronomy for Amateurs*** by Sidgewick for the observing side and you can learn at least 90 percent of what you need to know.

Rodger W. Gordon
637 Jacobsburg Road
Nazareth, PA 18064

Good Optics Cost Money

Dear Richard/ Thanks for coming by our display at the NCRAL convention in Rockford. I had set up my computer with my new optical design software to be able to show amateurs how telescope optics are designed and how the performance of various optical systems compare. Except for yourself, no one seemed interested in optical performance even though we had a record crowd at the meeting. To me this is an ominous sign of the health of our hobby.

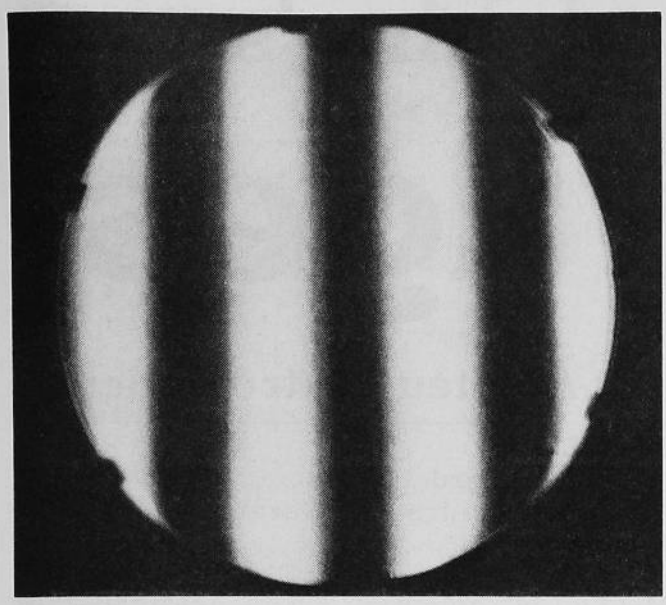
Today's beginners have the false hope that they can have a first-class, observatory-quality telescope for $1,000. As long as the novice's observations encompass no more than the usual Messier objects, these scopes do okay. But views of solar system objects are rudimentary at best and totally unsatisfying in some cases, so the novice concludes there isn't much to see. What could have become a rewarding and satisfying hobby dies because of mediocre optics.

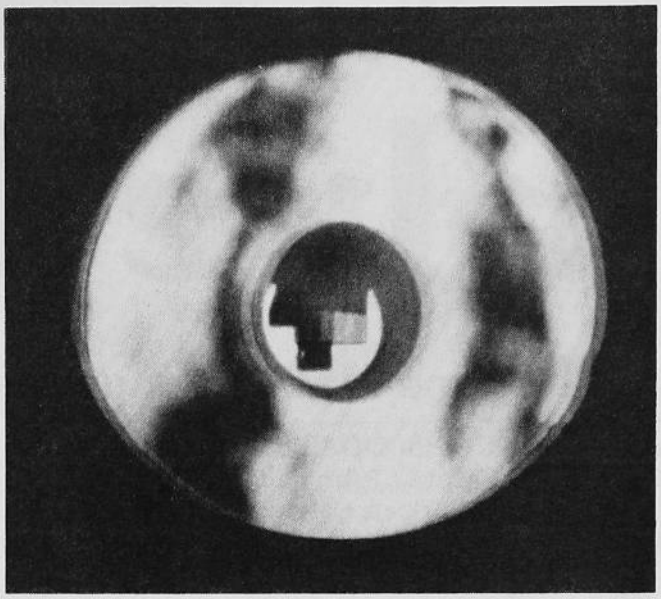
Don't people realize that quality costs money? To put a smooth 1/20-wave parabola on a 12-inch mirror requires hours of painstaking work by a very experienced optician. It also requires expensive lab test equipment to assure that this figure has been achieved. A really good 1/20-wave 12-inch mirror is worth a minimum of $2,000 because that's what it costs to make and test.

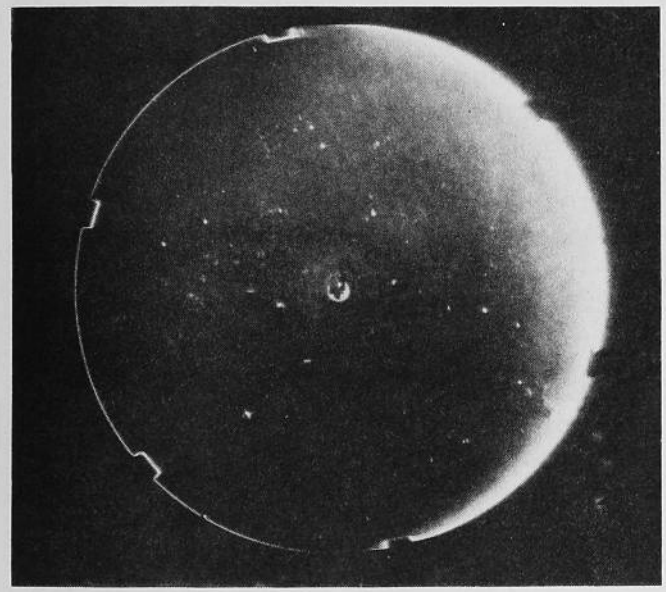
I fear for amateur astronomy if amateurs don't get smart about optics.

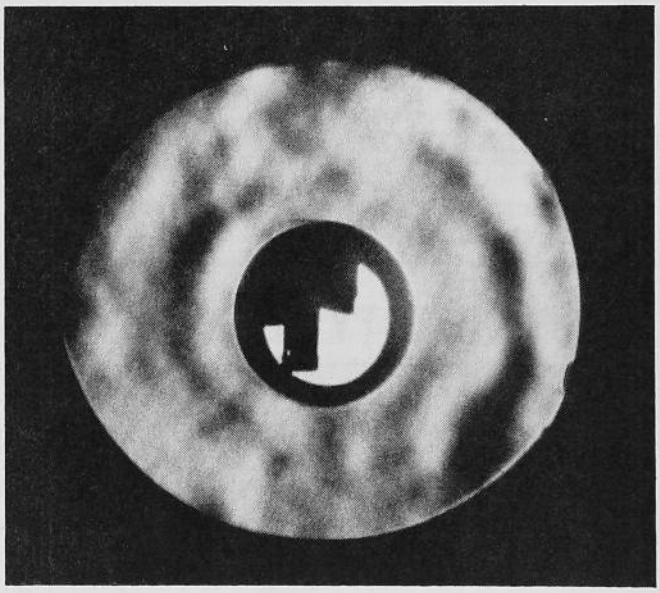
Roland Christen
Astro-Physics
7470 Forest Hills Road
Loves Park, IL 61111

-- The amateur telescope making community sets optical standards for the larger amateur community, and awareness of quality among telescope makers is growing. Because of this, I believe that awareness of optical quality will eventually spread throughout amateur astronomy, much as awareness of









quality sound spread from a small, hard-core hi-fi crowd thirty years ago.

Commercial Optics under Test

Dear Richard/ I am really pleased that the bubble is starting to burst with respect to the quality of commercial optics in amateur telescopes. The experiences you report in your editorial in *TM#36* and John Brooks' letter in *TM#35* verify my own test results: problems with poor optics are not isolated incidents. Enclosed are a few photographs illustrating the quality of two telescopes and an elliptical diagonal mirror.

The first photograph is of a 4-inch minor-axis elliptical flat advertised as 1/10-wave by a major telescope manufacturer. The interferometric test reveals that it is 1.5 waves convex, fully fifteen times worse than advertised. I ordered four flats in an attempt to get a good one. I thought I'd give the company a break the first time. Because I'm an optician myself, I know that a bad product can slip through even a reputable firm's quality control, but four times from the same manufacturer is too much.

The next pair shows a good 6-inch f/10 refractor objective under the Ronchi and Foucault tests. The Ronchi lines are straight, indicating a well-corrected wavefront, and very regular, indicating that the wavefront is *smooth*. Smoothness of figure is extremely important for contrast. Even so, this lens is by no means perfect. It has a narrow rolled edge, and the Foucault test reveals a faint yin-yang pattern indicative of slight astigmatism. However, this telescope is an excellent performer and these defects are not serious.

In contrast to this good telescope, the final pair of photographs illustrates a very poor optical system. This 8-inch f/10 Schmidt-Cassegrain has serious problems. The Ronchi pattern reveals a wavefront that is actually well corrected, but extremely rough. It looks even worse under the Foucault test. This telescope could not form a sharp star image when I compared it to an 8-inch f/4 Newtonian beside it.

I was glad to see that ASTRONOMY has started reviewing actual telescopes. Reviews of this nature have long been overdue. I believe, however, that amateur astronomers will have to pay higher prices if the manufacturers are forced to produce what they advertise. Advertising high-quality optics, spending the extra time to actually produce them, then charging amateur astronomers enough for it to pay bills and put bread on the table is a sure way for a company to go belly up!

Peter Ceravolo
Ottawa, Ontario

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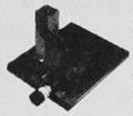

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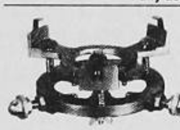

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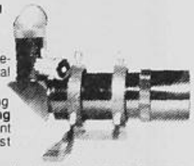

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Same Field with LUMICON coma corrector lens; note smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. It threads into LUMICON 2" EASY-GUIDERS for effortless installation. This lens is optimized for f/4.5 and reduces aberrations for f/3.5 to f/5 Newtonians. Off-axis images are much smaller, making off-axis guiding far easier and yielding round pinpoint star images in photos. Since star images are sharp over a full 2¼" circle, you can use medium format cameras in addition to 35mm cameras. This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Although designed for photography you may also use this lens to improve image quality in wide-field viewing with low power eyepieces.

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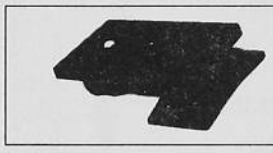
Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.

The ultimate in filter performance! The Lumicon Oxygen-III Filter has a contrast twice as high as the high performance Lumicon UHC Filter™. Use the Oxygen-III Filter for observing the very faintest planetary and diffuse emission nebulae. Also gives incredible views of bright nebulae (like M-27, M-17, etc.) from urban locations. Bandpass is 11nm, transmission is 90% for both O-III lines at 496nm and 501nm.

Filter Type	1¼"	48mm
Lumicon Oxygen-III	**$99.50**	**$199.50**
Lumicon UHC	**$99.50**	**$199.50**
Lumicon Deep-Sky	**$79.50**	**$119.50**
Set UHC and Oxygen-III .	**$190.00**	**$380.00**

NOTE: The Oxygen-III Filter is not a substitute, but a compliment to the UHC Filter. **1 year guarantee:** You must see nebulae with the O-III filter that are **invisible** without a filter.

NEW ADJUSTABLE PIGGYBACK MOUNT



LUMICON has just designed a new adjustable piggyback mount ideal for all telescopes of 8-14" aperture. It has **both** vertical and sideways adjustment to allow optical alignment. It was designed to allow mounting of the LUMICON SUPER-FINDER on C-8, C-14, etc., but is ideal for any telephoto lenses or small telescopes.

Deluxe Piggyback Mount **$45.00**
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LUMICON 12x80mm SUPER-FINDER . $170

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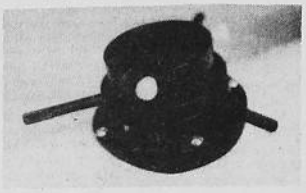

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LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½" above the telescope tube. Use the 1¼" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.
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†U.S. Patent 4,473,636

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U.S. Patent #4,448,500

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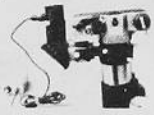

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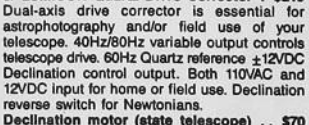

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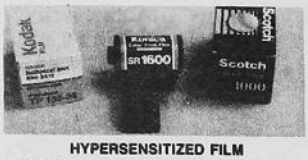

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12.5"	525	600
16.0"	1700	1950
18.0"	2300	★
20.0"	3400	★

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16.0"	1100	1350
18.0"	1300	★
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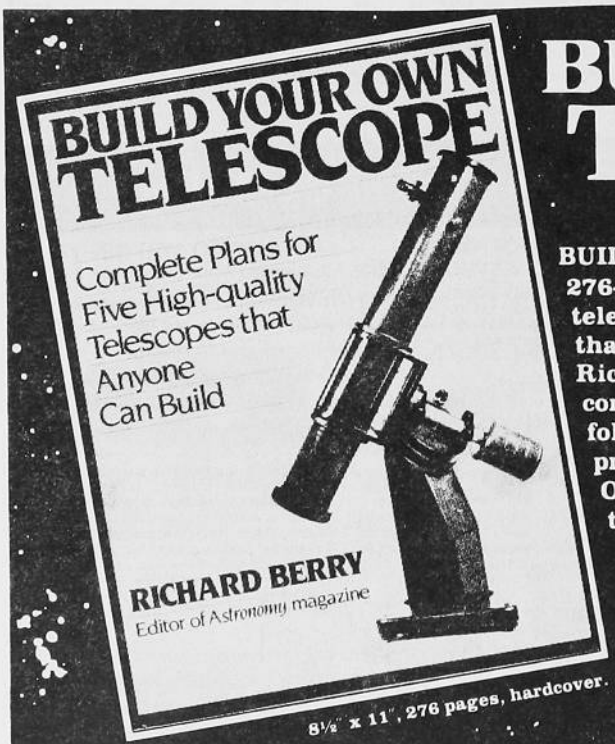

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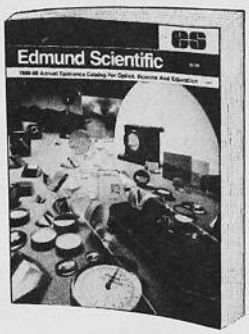

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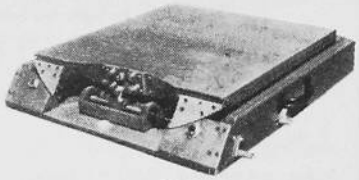

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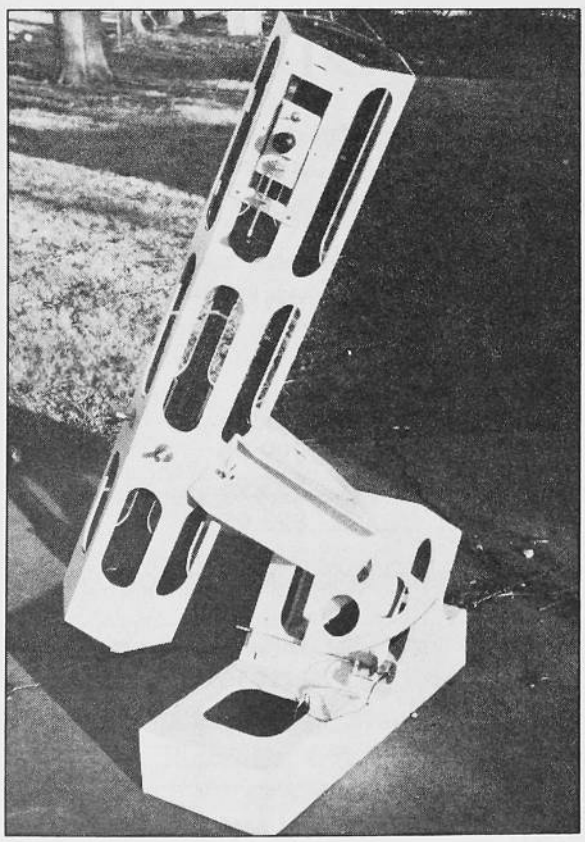

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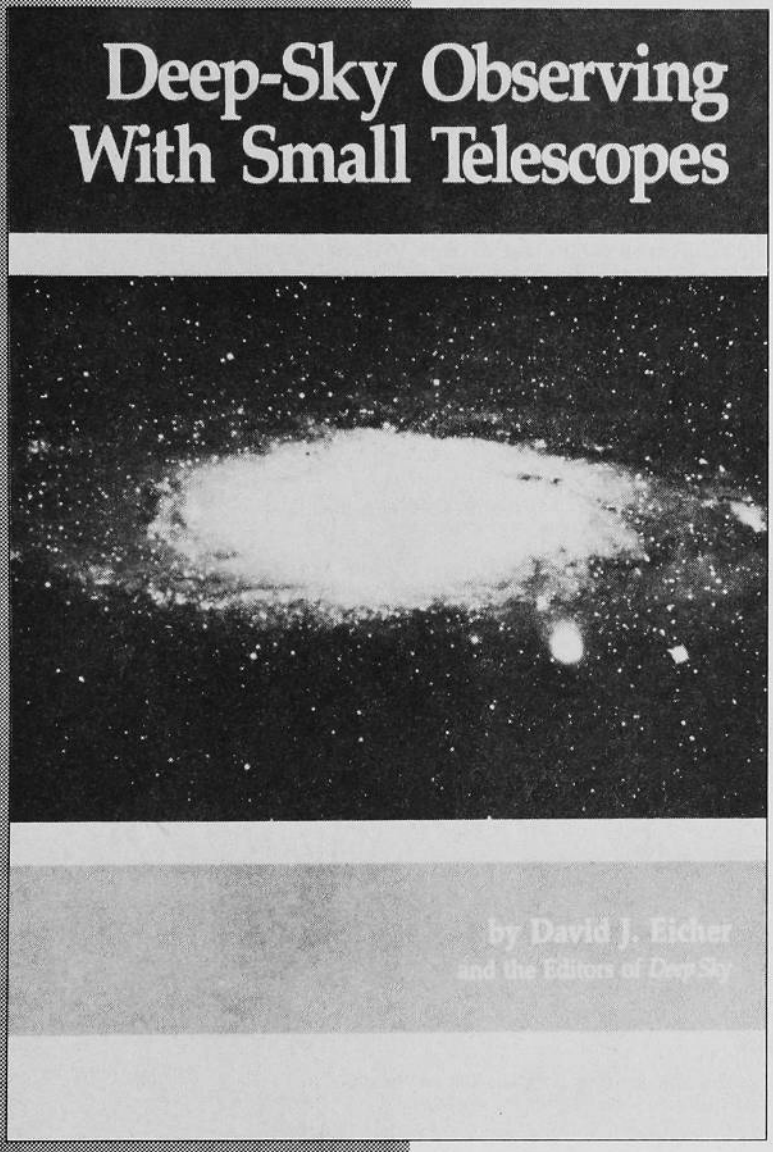

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